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REMSCAN FEASIBILITY STUDY
FINAL REPORT

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REMSCAN FEASIBILITY STUDY

FINAL REPORT

by

Canadian Marine Drilling Ltd.

October, 1984

The contents of this report reflect the views of the contractor and are not necessarily the official views or policies of the Transportation Development Centre, Transport Canada.

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17. Résumé

Ce rapport rend compte d'une étude de faisabilité concernant un système d'information sur les glaces flottantes, capable de fournir une information immédiatement utile aux navires et aux plates-formes de forage se trouvant dans les eaux canadiennes ou tout près. Ce système fait appel à un service de reconnaissance aérienne des glaces utilisant des radars dont les images sont transmises directement aux postes récepteurs équipés pour les recevoir. Un concept fondamental du système envisagé est la possibilité d'effectuer sur les lieux mêmes un traitement préliminaire et une première interprétation de l'information recueillie, à la lumière notamment des observations directes faites sur place. Cette information serait transmise par liaisons hertziennes sur bandes de fréquences étroites à un centre de coordination où l'ensemble de l'information reçue de plusieurs sources serait traité, constitué en base de données et restitué sous forme de carte synoptique montrant les conditions de glace, actuelles et prévues. Enfin, des blocs d'information correspondant aux besoins particuliers des utilisateurs leur seraient transmis sous forme de messages radio, de télécopie ou d'infographie, au choix. Les avantages escomptés d'un tel système sont l'instantanéité de l'information qu'il fournit, son action synergique, sa souplesse d'emploi, sa compatibilité et son économie. Le rapport fait état aussi de la mise au point d'un simulateur de navigation dans les glaces, utilisé pour montrer l'utilité pratique de l'information véhiculée par le système.

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17. Abstract

This report documents a feasibility study for a system providing timely sea ice information for operational support to users in Canadian and contiguous waters. The primary information source is airborne radar imagery, downlinked to sites equipped to receive it. A key concept is pre-processing and pre-interpretation of the imagery in the field (using locally available, complementary data) to permit significant information from many sites to be transmitted on low band-width channels to a central facility. There, all available information would be processed to form a comprehensive map data base of ice conditions, current and forecast. Packages of information selected for particular users would then be transmitted by radio message, facsimile, or special colour graphic modes, depending on the users' preferences. The advantages of the system include timeliness, synergism, flexibility, compatibility, and cost effectiveness. The study also included the development of a vessel transit simulator, which was used to demonstrate the strategic utility of ice information.

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SUMMARY

This document is the Final Report on the REMSCAN Feasibility Study. The Study was undertaken by the Transportation Development Centre, Transport Canada, to investigate the feasibility of an integrated system approach to the provision of ice information to support offshore activities, notably vessel transport of Arctic crude oil and other cargo, in the ice infested waters of North America.

An analysis of the needs of potential users was carried out, based on information obtained through a series of interviews and from previous studies. The analysis indicated that the needs of the significant categories of offshore users, namely, tankers and cargo vessels, fixed-site activities such as exploratory drilling operations, and oil spill response activities, could in all cases be met by nowcast and forecast ice descriptions at levels of coverage appropriate to strategic, tactical, and close-tactical situations. The needs of particular users are differentiated mainly by the distance scales and levels of detail which they require individually.

It was proposed that each user's requirements could be met by an appropriate "information package" consisting of the required strategic, tactical, and close-tactical information, delivered in a format compatible with his technical capability (i.e., one or more of colour graphic, monochrome graphic, or message formats).

The remainder of the report addresses the design of an integrated system capable of providing such information. A review of available and anticipated technology revealed that meeting the close tactical requirement or including the raw data sources (i.e., the totality of all users' sensors) within the framework of the REMSCAN system would be impracticable. These requirements were thus dropped and the scope of REMSCAN was accordingly restricted.

The system concept proposed comprised four major functional divisions:

- Remote Sensing (acceptance and processing of imagery)
- Navigation (image georeferencing and relative location of users)
- Communications (movement of information among various REMSCAN-equipped locations)
- System Control and Information Processing (assembly and maintenance of ice description and forecast data base)

In an actual, concrete design, the components of these functional subsystems would be physically distributed throughout the system, i.e. some of the Remote Sensing functions would be, for example, carried out on board vessels, and others would be carried out at a central facility.

Three distinct design approaches were identified:

- The Centralized Approach, in which all significant processing and interpretative functions are carried out at a central location with the field sites being relegated to the status of terminals.

- The Distributed Approach, in which all significant processing takes place in the field, with a central facility to serve a relatively minor coordinating and information archiving role.

- The Hybrid Approach, in which the interpretative and data processing functions are split between the field and central locations.,

Of these, the Hybrid Approach was recommended for development.

For an assumed, plausible, operational scenario, a baseline system was designed and cost estimates were obtained. Technical feasibility was thus established, based upon the use of available technology.

During the course of the Study, a number of areas of technical weakness were identified as candidates for design and development work. Correction of these deficiencies would be expected to improve system performance and reduce operating costs.

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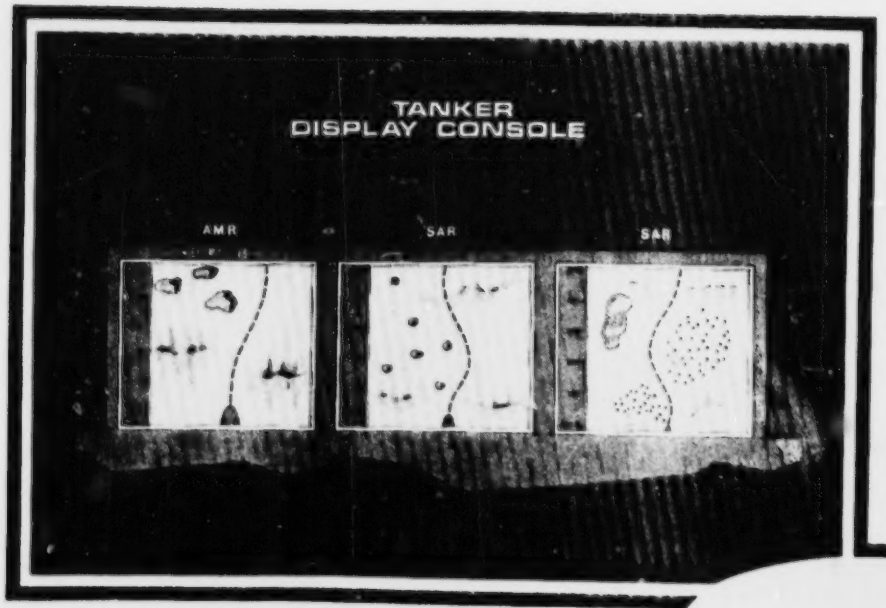
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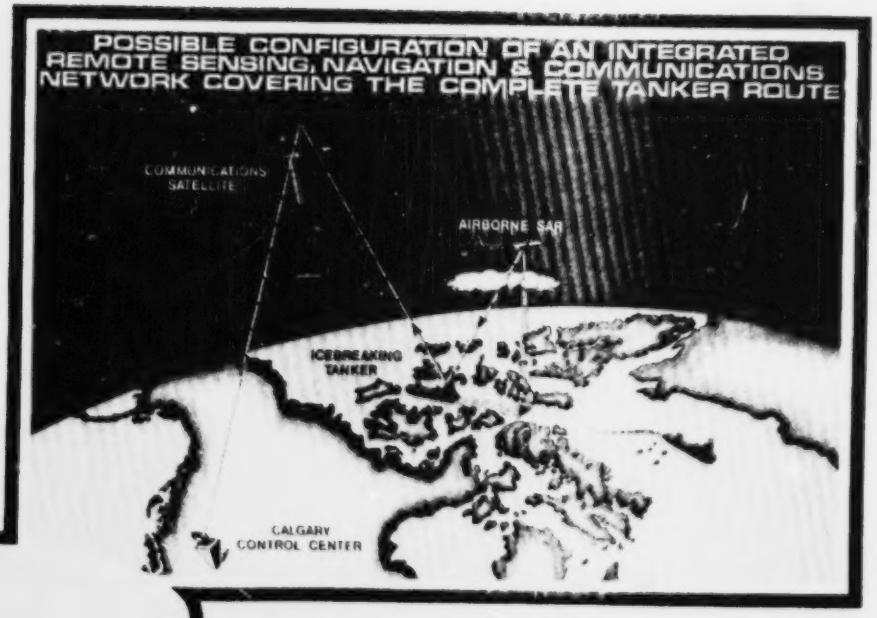
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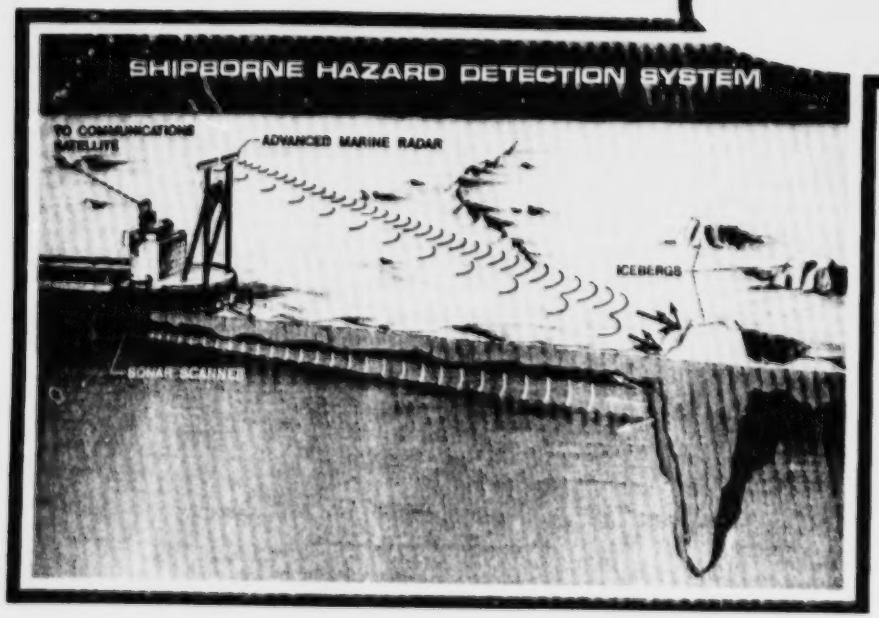
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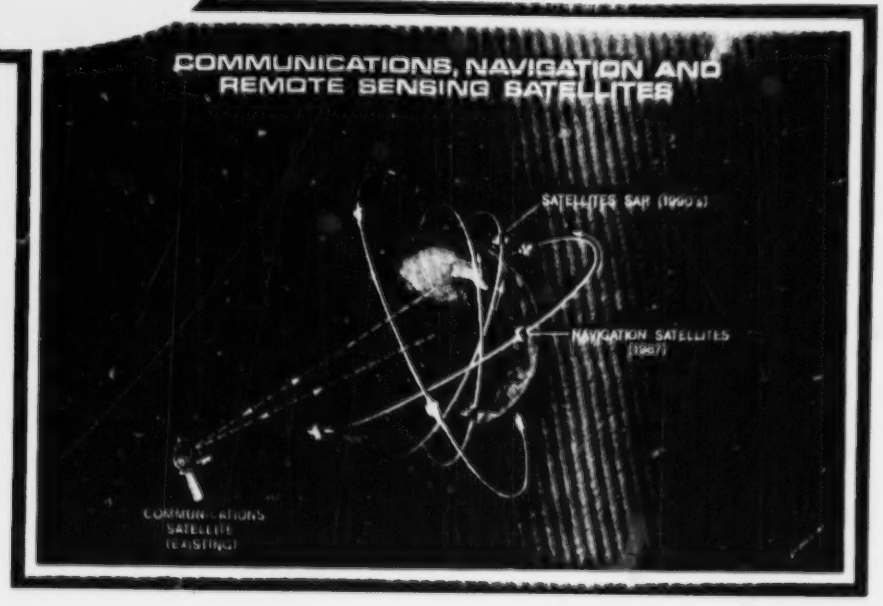
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1.0 INTRODUCTION

This document is the Final Report on the results of the REMSCAN Feasibility Study. This Study was carried out on behalf of Transport Canada by Canadian Marine Drilling Ltd. under DSS Contract Serial Number OSZ83-00017.

1.1 Background

The major commercial stimulus for development of Canadian offshore frontier areas is the existence in those regions of significant oil, gas, and mineral deposits. Large-scale exploration is currently underway, with exploitation of hydrocarbon deposits likely to commence in the late 1980's or early 1990's. Year-round offshore activities are presently and will continue to be involved.

Current offshore hydrocarbon exploration activities make use of floating platforms, pads of thickened fast ice, bottom-founded structures and dredged islands, sites which are designed to be either moveable or expendable. The commencement of production will see the addition of more substantial, semi-permanent facilities for extraction, processing, gathering, storage, and transportation of product. Most or all of these will be located offshore depending upon the development scenarios eventually adopted. The utilization of such facilities will require ongoing logistic support, and will be preceded by large scale offshore construction activities which will themselves require logistic support. A major element of such support will be marine transportation, both local and along corridors through the Bering Strait and Labrador Sea.

Similarly, the growth of mining and other land-based activities, especially in the high Arctic, will be accompanied by an increased level of marine traffic associated with product transportation and/or resupply needs.

The preservation of sovereignty is the major non-commercial stimulus for development. At present, scattered settlements and outports throughout this vast, virtually unpopulated region are resupplied by means of annual sea lifts originating from Montreal in the east and Mackenzie river points in the west.

Concerns have been expressed that with development will come potential for environmental pollution. Although great planning and design effort has gone and will continue to go into prevention of major mishaps, the maintaining of detailed contingency plans together with the means for their implementation continues to be a major aspect of commercial development activity. Oilspill response will involve marine and shore based cleanup operations and substantial logistic support, itself requiring marine and other transport.

1.2 The Role of Ice in Offshore Activities

The dominant factor in the northern offshore environment is the more-or-less continuous presence of ice in various forms and concentrations.

This factor serves to distinguish northern offshore activities from their counterparts elsewhere. Ice can impede the movement and threaten the safety of vessels, can block transportation corridors thus increasing accident risks, can jeopardize fixed-site installations, and can hinder oil spill cleanup activities. On the other hand certain operations such as, for example, the installation and maintenance of subsea pipelines and deep water drilling from ice pads would in fact benefit from the dependable presence of stable, fast ice.

Clearly, there are needs for various types of information on the whereabouts of particular forms of ice at sea and on their movements. In some situations ice information would be readily usable only when coupled with other information such as, for example, the locations of reefs and other navigational hazards.

1.3 Statement of the Problem

The underlying impetus which has led to the REMSCAN concept is operational experience in ice-infested waters, initially by oil companies operating in the Beaufort Sea and, more recently, by the M.V. Arctic in its pioneering voyages in the eastern Arctic.

This experience shows that ice information which at present provides both essential and desirable support to all phases of offshore operations including marine transportation, may be divided into two fundamentally distinct categories:

- Information acquired by vessels/sites autonomously. This information includes visual observation, marine radar data, local meteorological and oceanographic data together with simple data processing primarily to enhance information display.

- Information acquired from external sources. This includes imagery obtained from airborne radar, satellite photos, weather forecasts provided by AES, and from a historical data base which provides synoptic information on sea ice cover.

The primary question addressed by REMSCAN Study is to what extent a closely coordinated effort among various government and industry data sources, especially external sources, can provide at reasonable cost comprehensive information covering a range and time span not otherwise accessible to the user.

REMSCAN would coordinate the functions of diverse resources including personnel, hardware, software, and equipment in order to maximize the usefulness of whatever ice data might be available.

The Study investigates the feasibility of a coordinated, multi-user approach to the acquisition, processing, and dissemination of ice information found through experience to be useful/desirable in the conduct of safe, effective offshore operations, including oil spill response operations.

2.0 STUDY APPROACH

The methodology employed in carrying out this study is as follows:

a) Analysis of the general needs of a representative cross-section of those involved directly in offshore activities or in supporting roles. The needs have been identified through discussion of operational experience and future (assumed) operational scenarios and are detailed only to that extent necessary to place design limits on the kinds and quantities of information needed, and where and when it is needed.

b) Vessel Transit Simulator. As a part of this work, a Vessel Transit Simulator was developed and used to demonstrate the benefit of strategic ice information to the transit time of a vessel.

c) Characterization of the needed information in terms of suitable "Information Packages". By this term is meant a class of information (e.g., 4-colour maps), all items of which are similar from the information handling point of view.

d) Demonstration of the technical feasibility of a system to provide such packages. The term "system" is used here in a broad sense, and may include not only computer hardware and software, but also personnel, equipment, services and facilities which may be procured by leasing, by secondment from participating organizations, or which may be owned by a hypothetical REMSCAN co-ordinating agency.

2.1 Systems Approach

A systems approach has been adopted for the REMSCAN Study. In practice, this implies a front-to-back process which aims to describe the system:

- First in terms of a set of simple performance goals
- Next, in terms of a set of functions it must carry out in order to achieve those goals, and
- Finally, in terms of actual equipment, etc., with which those functions can be implemented.

This multi-level process necessarily treats the system as a single entity and so contributes to the achievement of design consistency and effectiveness.

3.0 ICE INFORMATION NEEDS

REMSCAN originated as a specialized in-house concept tailored to Canmar's needs. In extending REMSCAN to a multi-user concept with a wider zone of coverage, it was necessary to review and redefine in-house goals to ensure consistency with those of the users at large. The following information sources were utilized:

- The offshore oil and gas industry
- Government departments
- Prior studies.

In addition, the cumulative experience in Beaufort Sea offshore activities vested in Canmar's operational personnel was accessible to the study team on an informal, as-needed basis.

3.1 REMSCAN Conceptual Framework

In determining the user needs and system requirements for REMSCAN, it was necessary to define a conceptual starting point in terms of certain assumptions. These are listed below:

- REMSCAN is to be a source of comprehensive ice and related information at all locations within the ice infested areas of North American coastal waters. This study is concerned primarily with the needs of Canadian users including those transiting U.S. Arctic waters. Thus it will be assumed that REMSCAN coverage extends to and includes the Bering Sea.
- Information is to be tailored to individual users and/or specific applications.
- System development and frontier development are to be in-phase.
- All necessary and available sources of information without restriction may be utilized to achieve comprehensive coverage.
- REMSCAN shall be compatible with other existing and proposed information systems.
- REMSCAN is to be upwardly compatible with emergent technologies.

3.2 Information Sources

3.2.1 Interviews

A series of interviews was carried out with organizations having an interest in REMSCAN. A typical interview consisted of a brief presentation to provide background on REMSCAN concepts and on the Study, followed by a round-table discussion covering the following topics:

- Projected scenario for development of northern activities
- Impact of ice on operations, present and future
- Operational responses to situations which could occur
- Role of ice and related information in such responses
- Mode of utilization of information.

A list of industrial users interviewed together with a description of their respective areas of operation is as follows:

- Panarctic Oils (Arctic Islands)
- Petro-Canada (East Coast: possibly High Arctic and Beaufort Sea in future)
- Gulf Canada Resources (Beaufort Sea: possibly High Arctic and East Coast in future)
- Melville Shipping (Northwest Passage, East Coast)
- Canarctic Shipping (High Arctic, East Coast: possibly other areas in future).

Government organizations interviewed fell into two categories:

- Those involved directly in carrying out or coordinating activities which could benefit from REMSCAN information. This group includes the Canadian Coast Guard, who assist and regulate coastal shipping, DIAND, and EPS (Environment Canada) who have responsibilities in the areas of oilspill response and contingency planning.

- Those involved in providing information services which are related to REMSCAN. This group includes AES (Environment Canada), the Radarsat Project (Energy, Mines & Resources) and the Canadian Hydrographic Service (Fisheries and Oceans). CHS could also, by virtue of its survey program, be included as a minor user under category (a) above.

3.2.2 Other Studies

3.2.2.1 Radarsat

Radarsat is aimed at providing ice and ocean information by means of satellite imaging radar. Consequently its potential applications are a subset of those foreseen for REMSCAN. The comprehensive Survey of User Requirements conducted for Radarsat was however sufficiently broad in scope to be of interest and use in the present study (1).

3.2.2.2 Related Documentation

Planning of REMSCAN functions must recognize the constraints imposed by major technical developments planned in related areas. Such developments include:

- MSAT, a Canadian UHF direct broadcast satellite
- The Atmospheric Environment Service (AES) proposed Ice Centre Program Expansion
- NAVSTAR, a U.S. multi-satellite Global Positioning System

Documentation which has contributed to an understanding of their impact on REMSCAN is included in the Bibliography.

3.3 Operational Basis of Ice Information Needs

Four major operational categories requiring ice information have been identified:

- Vessels permitted to operate independently
- Vessels requiring an escort
- Offshore fixed sites
- Oilspill-related activities

Although there are marked differences in the ice information required to support each of these, their needs can be classified generally as follows:

- Strategic information covering a broad region with forecast periods exceeding several days. For example, in the case of a tanker travelling from the Beaufort Sea to Quebec, this could encompass almost the entire ice infested region over a two week period.

- Tactical information covering a range which might be encountered within 24 hours. Again, using the tanker example, interpreted imagery covering a 500 km swath ahead of the vessel, with resolution better than 5 km - sufficient to show major ice features and leads - would be required, together with forecasts at 12 hour intervals.

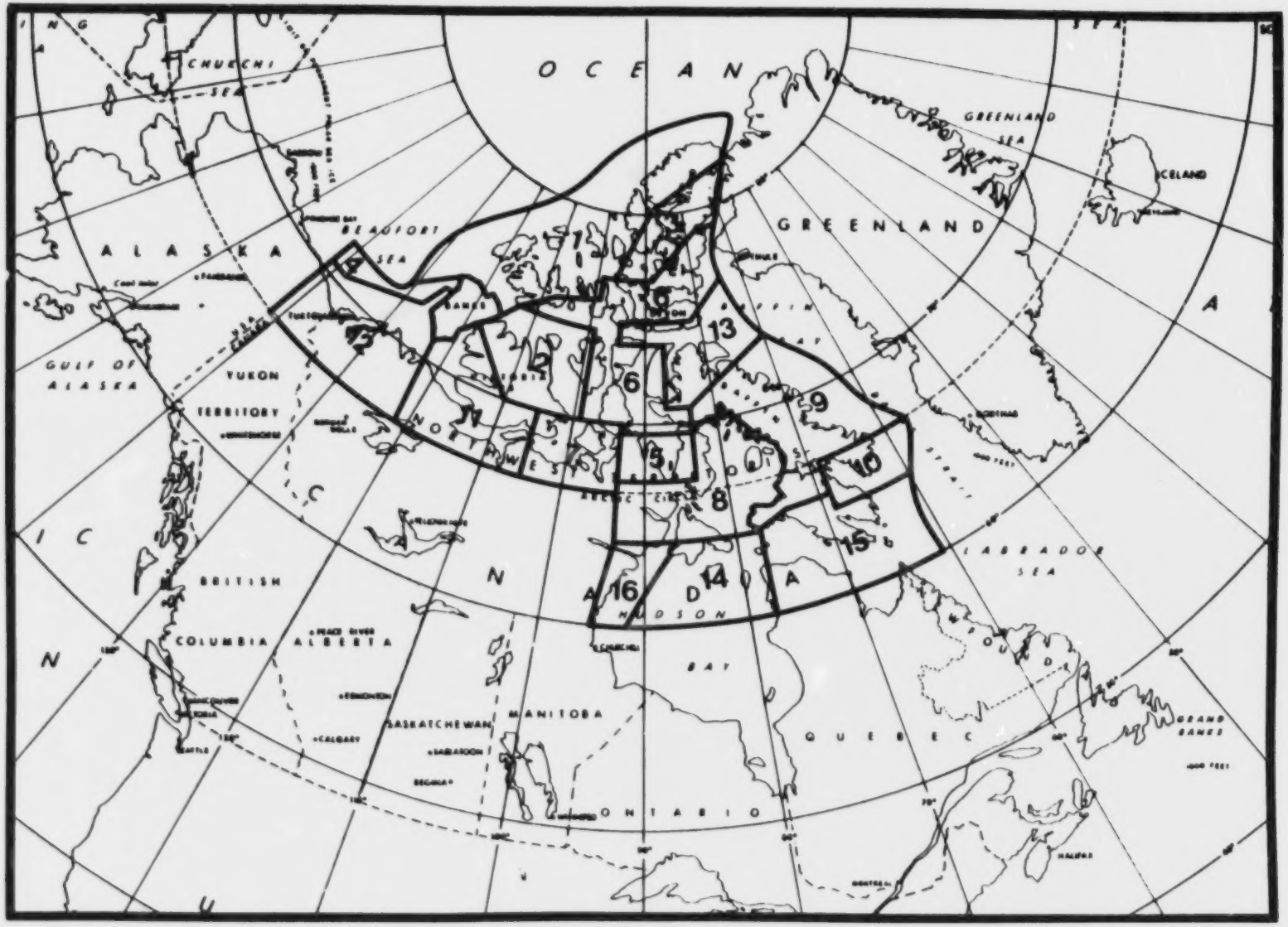
- Close tactical information covering situations which must be handled within an hour. For the tanker this could be SAR imagery covering a 15-25 n.mi. swath ahead of the ships with resolution sufficient to show ridges, etc. Marine radar position fixes could be used to determine the ship's position with respect to ice features identifiable from the imagery between updates.

- Route optimization for vessels, a special form of strategic information. It would be based on up-to-date ice conditions and forecasts, a knowledge of the operating characteristics of the vessel in question, and computer transit simulation using agreed-upon scoring schemes (see Section 3.5). Optimization would be carried out on demand in near-real time, and would take into account levels of detail down to the tactical level. Update frequency would depend upon frequency of forecasts

3.3.1 Vessels

The distinction between those vessels which do require an escort and those which do not is prescribed by the Arctic Waters Pollution Prevention Act. The Act regulates access according to vessel class, time and place (see Figures 1 and 2).

Escorted vessels require only close tactical information; the burden of acquiring strategic and tactical information falls upon the escort vessel. The ice information needs of the latter will of course be modified by the presence of the client (secondary) vessels depending on the convoy configuration and individual vessel capabilities.



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: SHIPPING SAFETY CONTROL ZONES - FROM ARCTIC POLLUTION PREVENTION ACT
		FIGURE No. 1

Column I Category	Column II Zone 1	Column III Zone 2	Column IV Zone 3	Column V Zone 4	Column VI Zone 5	Column VII Zone 6	Column VIII Zone 7	Column IX Zone 8	Column X Zone 9	Column XI Zone 10	Column XII Zone 11	Column XIII Zone 12	Column XIV Zone 13	Column XV Zone 14	Column VXI Zone 15	Column XVII Zone 16
Arctic Class 10 1.	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
Arctic Class 8 2.	Jul. 1 to Oct. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
Arctic Class 7 3.	Aug. 1 to Sep. 30	Aug. 1 to Nov. 30	Jul. 1 to Dec. 31	Jul. 1 to Dec. 15	Jul. 1 to Dec. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
Arctic Class 6 4.	Aug. 15 to Sep. 15	Aug. 1 to Oct. 31	Jul. 15 to Nov. 30	Jul. 15 to Nov. 30	Aug. 1 to Oct. 15	Jul. 15 to Feb. 28	Jul. 1 to Mar. 31	Jul. 1 to Mar. 31	All Year	All Year	Jul. 1 to Mar. 31	All Year	All Year	All Year	All Year	All Year
Arctic Class 4 5.	Aug. 15 to Sep. 15	Aug. 15 to Oct. 15	Jul. 15 to Oct. 31	Jul. 15 to Nov. 15	Aug. 15 to Sep. 30	Jul. 20 to Dec. 31	Jul. 15 to Jan. 15	Jul. 15 to Jan. 15	Jul. 10 to Mar. 31	Jul. 10 to Feb. 28	Jul. 5 to Jan. 15	Jun. 1 to Jan. 31	Jun. 1 to Feb. 15	Jun. 15 to Feb. 15	Jun. 15 to Mar. 15	Jun 1 to Feb. 15
Arctic Class 3 6.	Aug. 20 to Sep. 15	Aug. 20 to Sep. 30	Jul. 25 to Oct. 15	Jul. 20 to Nov. 5	Aug. 20 to Sep. 25	Aug. 1 to Nov. 20	Jul. 20 to Dec. 15	Jul. 20 to Dec. 31	Jul. 20 to Jan. 20	Jul. 15 to Jan. 25	Jul. 5 to Dec. 15	Jun. 10 to Dec. 31	Jun. 10 to Dec. 31	Jun. 20 to Jan. 10	Jun. 20 to Jan. 31	Jun. 5 to Jan. 10
Arctic Class 2 7.	No Entry	No Entry	Aug. 15 to Sep. 30	Aug. 1 to Oct. 31	No Entry	Aug. 15 to Nov. 20	Aug. 1 to Nov. 20	Aug. 1 to Nov. 30	Aug. 1 to Dec. 20	Jul. 25 to Dec. 20	Jul. 10 to Nov. 20	Jun. 15 to Dec. 5	Jun. 25 to Nov. 15	Jun. 25 to Dec. 10	Jun. 25 to Dec. 20	Jun. 10 to Dec. 10
Arctic Class 1A 8.	No Entry	No Entry	Aug. 20 to Sep. 15	Aug. 20 to Sep. 30	No Entry	Aug. 25 to Oct. 31	Aug. 10 to Nov. 5	Aug. 10 to Nov. 20	Aug. 10 to Dec. 10	Aug. 1 to Dec. 10	Jul. 15 to Nov. 10	Jul. 1 to Nov. 10	Jul. 15 to Oct. 31	Jul. 1 to Nov. 30	Jul. 1 to Dec. 10	Jun. 20 to Nov. 30
Arctic Class 1 9.	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sep. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	Jul. 15 to Oct. 20	Jul. 1 to Oct. 31	Jul. 15 to Oct. 15	Jul. 1 to Nov. 30	Jul. 1 to Nov. 30	Jun. 20 to Nov. 15
Type A 10.	No Entry	No Entry	Aug. 20 to Sep. 10	Aug. 20 to Sep. 20	No Entry	Aug. 15 to Oct. 15	Aug. 1 to Oct. 25	Aug. 1 to Nov. 10	Aug. 1 to Nov. 20	Jul. 25 to Nov. 20	Jul. 10 to Oct. 31	Jun. 15 to Nov. 10	Jun. 25 to Oct. 22	Jun. 25 to Nov. 30	Jun. 25 to Dec. 5	jun. 20 to Nov. 20
Type B 11.	No Entry	No Entry	Aug. 20 to Sep. 5	Aug. 20 to Sep. 15	No Entry	Aug. 25 to Sep. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	Jul. 15 to Oct. 20	Jul. 1 to Oct. 25	Jul. 15 to Oct. 15	Jul. 1 to Nov. 30	Jul. 1 to Nov. 30	Jun. 20 to Nov. 10
Type C 12.	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sep. 25	Aug. 10 to Oct. 10	Aug. 10 to Oct. 25	Aug. 10 to Oct. 25	Aug. 1 to Oct. 25	Jul. 15 to Oct. 15	Jul. 1 to Oct. 25	Jul. 15 to Oct. 10	Jul. 1 to Nov. 25	Jul. 1 to Nov. 25	Jun. 25 to Nov. 10
Type D 13.	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20	Aug. 15 to Oct. 20	Aug. 5 to Oct. 20	Jul. 15 to Oct. 10	Jul. 1 to Oct. 20	Jul. 30 to Sep. 30	Jul. 10 to Nov. 10	Jul. 5 to Nov. 10	Jul. 1 to Oct. 31
Type E 14.	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Sep. 30	Aug. 20 to Oct. 20	Aug. 20 to Oct. 15	Aug. 10 to Oct. 20	Jul. 15 to Sep. 30	Jul. 1 to Oct. 20	Aug. 15 to Sep. 20	Jul. 20 to Oct. 31	Jul. 20 to Nov. 5	Jul. 1 to Oct. 31

CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: ACCESS TO ARCTIC WATERS FROM ARCTIC POLLUTION PREVENTION ACT
		FIGURE No. 2

In addition to having actual and forecast data as aids to navigation, it is desirable that vessels be provided with the capability to select routes which are optimal in the sense that they minimize transit time, the amount of required escort support, operating cost, or some other quantity. Route optimization would be carried out at both the tactical and strategic levels. The latter might be, in some cases, accomplished by inspection. Tactical optimization might on the other hand require considerable computation in order to quantitatively evaluate complex route options.

3.3.2 Offshore Fixed Sites

These are for the most part oil and gas industry-related. They include:

- Artificial islands.
- Bottom-founded structures, with and without berms.
- Construction sites related to the preceding two items and to pipeline-laying activities.
- Floating rigs, including drillships.

The response of an offshore site to a perceived ice hazard is governed by a set of Ice Alert Procedures, specific to the site and influenced by the degree of protection against ice hazards inherent in its design. The procedures govern the deployment of available ice management resources (icebreakers, etc.), and ensure that the kind and level of activity taking place are consistent with the time available to attain secure status. The time necessary to wind down an activity may be as short as a few minutes or as long as several days. The time available is estimated with the aid of an ice information system, utilizing ice surveillance, tracking, and prediction, whose function is to forecast hazardous ice situations with as much lead time as possible.

3.3.3 Oilspill-Related Activities

The immediate objective of an oilspill response is containment of the spill, followed by cleanup. Both phases involve large quantities of equipment, materials, and personnel. The logistics of assembling and deploying these resources will be influenced strongly by the presence and movement of ice. It is therefore essential that the oilspill On-Scene Commander have access to comprehensive ice information including forecasts in the spill region.

When substantial open water areas are present, tracking of the spilled oil may be complemented by oil drift (spill development) forecasts requiring substantial computational capacity and environmental data input. The presence of consolidated ice cover tends to inhibit spreading and therefore simplifies the tracking problem. However, where oil is trapped beneath ice, cleanup must be postponed until the oil surfaces. Surveillance may thus be required for long periods of time.

Further oilspill-related needs, for surveillance and control of local air traffic, have been expressed. These are noted, but are considered to lie outside the scope of REMSCAN.

3.4 Influence of Time and Place on Information Needs

A qualitative summary of the motion of ice as a function of time and place is shown in Figure 3. This matrix indicates large regions where, except for a brief period during the summer and fall, no significant movement of ice takes place. All regions experience moving ice during a part of the year, with frequent ice incursions present under nominally open water conditions. In some regions, such as Baffin Bay and the Beaufort-Chukchi Seas, periods of stable ice are non-existent (except within narrow inshore regions). In most areas of the High Arctic, there are periods in which irregular and infrequent motion of continuous ice cover occurs.

In regimes where motion is, or is expected to be, significant, surveillance frequencies will be determined by the need to keep track of and to predict the changing distribution of ice. Even in the fast ice regime, surveillance may be needed to assist in detecting and predicting regions of ice pressure, subject to the as-yet undemonstrated technical feasibility of so doing if traffic warrants.

It should be noted that substantial variations occur in the times of transition from moving to stable ice, and vice-versa. Planning and scheduling of intensive ice surveillance is therefore dependent upon reliable forecasting of these events. A secondary need for monitoring of the associated causative factors such as weather conditions is thus foreseen throughout the year.

3.5 The Need for Strategic Information: A Simulator Study

A question has been raised concerning the value of strategic and tactical information as aids to navigation. In other words, does information on ice beyond the range of a ship's sensors confer significant benefits?

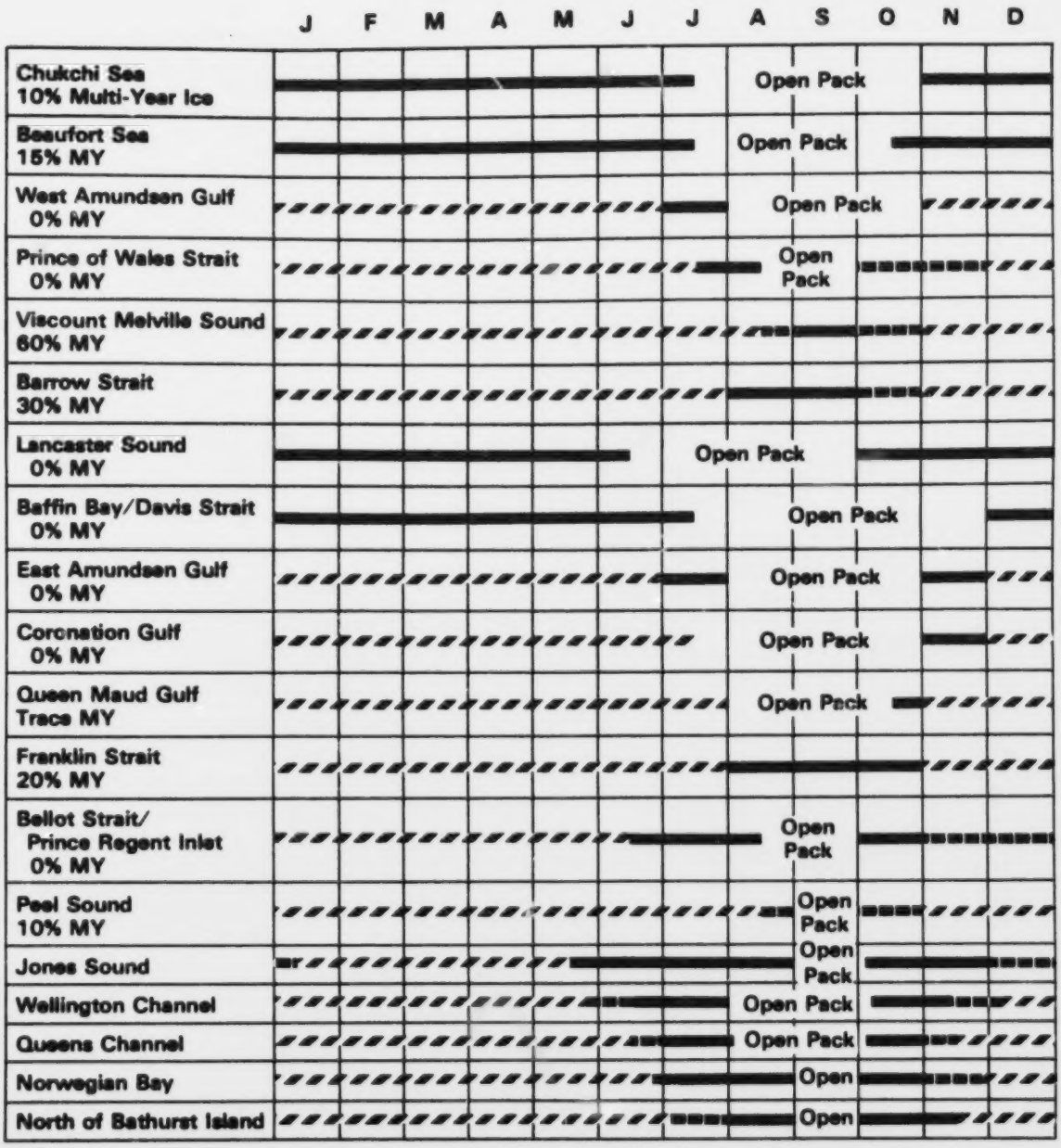
This question was addressed in the Study through the use of a Vessel Transit Simulator designed specifically to simulate a vessel transiting a region characterized by any or all of open water, land forms, and several types of ice.

The Simulator comprised an Orcatech 2000 Colour Graphics Computer and a software package. The software was developed by the McElhanney Group under Canmar direction, and included a ship model developed by Canmar.

A fully documented description of the Simulator including software source code listings has been delivered to TDC and, with minor editorial revisions, is included in a separate volume of this Report as Appendix A.

3.5.1 Simulator Description

The Simulator displays in real time (or in accelerated time if desired) the trajectory of a ship symbol on a colour-coded chart representing an icescape. The icescape allows the following features to be displayed:



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: ICE MOVEMENT IN ARCTIC TRANSPORTATION ROUTE SEGMENTS - QUALITATIVE SUMMARY
		FIGURE No. 3

- Landforms
- Open water
- Icebergs
- Floes (first, second, and multi-year)
- Floe ridging (selectable orientation and spacing)

An icescape can be entered into the Simulator by a user via a digitizing tablet and keyboard annotation.

Ship motion is controlled by the operator using a joystick to select rudder angle and engine power. The response of the ship is determined by these inputs, by the ship's existing state of motion, by ice conditions at its location, and by internal model parameters. The latter correspond roughly to the Canmar Kigoriak, but can be easily modified to permit the simulation of other vessels.

At the conclusion of a trip, the following performance statistics are presented.

- Straight-line distance travelled.
- Along-path distance travelled.
- Total elapsed time.
- Average velocity.
- Average power level.

3.5.2 Display Modes

Several display modes corresponding roughly to the level of information available from:

- Visual observation ("Visual" mode)
- Marine radar at several range settings ("Radar" mode)
- Interpreted airborne radar on several scales ("SLAR" mode)

are available.

Display mode control affords a means to gauge the effect of the level of ice information available to the ship's Master, on overall performance. The three modes are described in more detail in the following paragraphs.

3.5.2.1 "Visual" Mode

In this mode the display range is selectable between the limits of one and two nautical miles. Full colour coding ensures that all information characterizing local ice conditions is available. This level of information may be described as "close-tactical".

3.5.2.2 "Radar" Mode

In this mode, the level of information may be described as "tactical". The display ranges vary from 2 to 20 nautical miles, and some information is suppressed. Land, open water, and ice ridges are

displayed, but first, second, and multi-year ice are assigned a common colour code and are therefore not distinguishable.

3.5.2.3 "SLAR" Mode

The information available in this mode is roughly equivalent to the "strategic" level. The display range varies from 20 to 55 nautical miles. Full information is displayed as for the "Visual" Mode, but gray-scale representation is used instead of colour-coding in order to achieve greater realism.

3.5.3 Usage and Results

Three detailed icescapes covering the region from the northeastern end of Prince of Wales Strait to eastern Lancaster Sound were prepared. Ice conditions were generally representative of late July, and in certain areas were based directly on airborne radar imagery.

Two simulated transits of the region from west to east were carried out under the supervision of a test conductor who was responsible for control of the display mode. The vessel was driven by a qualified ship's Master with icebreaker experience.

During the first transit, only "Visual" and "Radar" mode information were made available, corresponding to the close-tactical and tactical cases. A second transit was simulated several days later, using the same icescapes and the same personnel. During the second transit however, strategic information was made available to the Master at his request. The results of these runs are presented in Table 1.

The overall average speed increase of 17% obtained when using extended range ("SLAR" mode) information is significant and tends to substantiate the hypothesis that strategic information is a useful navigational tool. The improvement varies substantially from one icescape to the next, and is clearly dependent upon ice conditions as well as human factors. Note that no route optimization other than by inspection took place. It is clear that further exploration of navigational strategies and aids by means of the simulator would be extremely useful. Recent experiences aboard the M.V. Arctic also support this hypothesis; however, the subject requires careful analysis in particular with respect to the boundaries of "tactical" and "strategic".

TABLE 1
SIMULATOR PERFORMANCE STATISTICS

Icescape	Radar/Visual Only			Radar/Visual/SLAR		
	Path Length (n.mi)	Elapsed Time (hours)	Average Speed (knots)	Path Length (n.mi)	Elapsed Time (hours)	Average Speed (knots)
#2 Prince of Wales St. and Western Vis. Melville Sd.	169.36	34.31	4.94	162.38	26.38	6.16
#14 Eastern Vis. Melville Sd.	141.19	16.68	8.46	141.53	15.48	9.14
#13 Barrow St and Lancaster Sd.	137.58	9.66	14.24	130.60	8.40	15.54
Totals/Averages	448.13	60.65	7.39	434.51	50.26	8.65

4.0 INFORMATION PACKAGES

It is proposed that, for each user, all needed ice information be assembled into a "package" which would be technically compatible with the communication and display equipment at his disposal (e.g., colour graphics).

The components of such a package would comprise some or all of:

- Strategic information
- Tactical information
- Close-tactical information
- Route optimization information

on time scales and for regions appropriate to the user's situation. In other words the strategic component, for example, would conform to the particular user's definition of "strategic" and would be referenced to his location. For other similarly equipped users, the packages would be similarly configured, but would of course have different information contents.

Note that the terminology used to describe the preceding categories, e.g., "Strategic", refers to the time scale and geographical coverage, and not necessarily to the usage to which the information is put. For example, a certain range of information might be used for tactical purposes by a tanker in the Beaufort Sea, whereas the same information would constitute a strategic planning tool to a drillship. This distinction is illustrated in Figure 4.

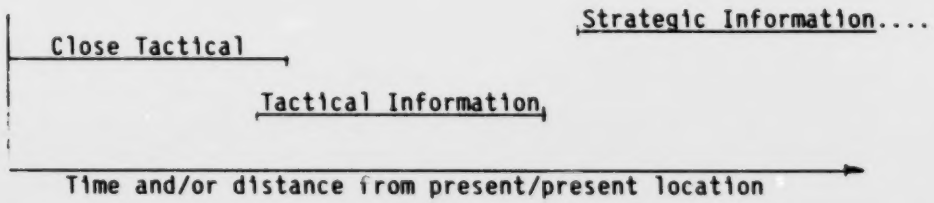


FIGURE 4
USAGE RANGE OF INFORMATION PACKAGE COMPONENTS

4.1 Package Configurations

Packages would be assembled using one or more of the following information configurations:

- Imagery
- Colour-coded maps
- Monochrome charts
- Message/Text

Note that some of these might be excluded after further analysis. Note also that standardization of data formats has not been imposed at this point. For example, a message/text configuration could be supported by printer, fax, or even voice formats.

4.1.1 Imagery

Imagery consists of high resolution photographic-quality information detailing the physical form of surface features. By virture of its complexity, imagery may contain implicit information on quantities such as ice type which are not themselves directly observable. Such information would normally be extracted from the imagery by subsequent processing and skilled interpretation.

4.1.2 Colour-Coded Maps

These are schematic representations of the geographical distribution of specific quantities, based on information extracted from imagery, derived from other sources, or both. For example, a map may distinguish ice, water, and land by means of three different colours, all other information being suppressed. Maps are end products of analysis and interpretation. While their raw information content, in the sense of communications theory, may be low relative to imagery, their content of <u>significant</u> information is usually very high.

Colour coded maps may include "texture coding" as well. An example of texture coding would be the use of crosshatching to provide additional means for distinguishing, say, multi-year ice from other types. With the use of high-resolution media, a large amount of information may be packed into a combination colour and texture-coded map.

4.1.3 Monochrome Charts

Black and white charts are perhaps the most familiar end products of analysis and interpretation, and are widely used to convey weather as well as ice information. They obviously cannot convey as much information to the user as colour-coded maps, but have the advantage of being compatible with low cost media. For the same amount of information, either more monochrome charts would be required, or supplementary (message/text) information would have to be appended.

4.1.4 Message/Text

This configuration is at present used chiefly for broadcast weather information, for annotation of other information (see Subsection 4.1.3), or for specific information requests.

There are no apparently fundamental reasons which would preclude its use to convey strategic, tactical, or even close-tactical information. It is however difficult to see how the latter type of information could be presented on a timely basis in such a configuration except by the issuance of direct instructions, e.g., "turn 30 degrees to port". Such a scenario would however appear to be unlikely under normal circumstances.

4.2 Information Package Content

In this section, the components of information packages are described in detail sufficient to establish the major constraints which they impose on REMSCAN System Design.

4.2.1 Strategic Information

General Description: A synoptic representation of ice-conditions over the maximum region of interest to a particular user. For example, the strategic range for a drillship would be 200 km (approximately 4-8 days range at typical summer floe drift speeds), whereas for a Class 10 tanker, the range could extend from the Beaufort Sea to the Gulf of St. Lawrence covering a time period of 2 or 3 weeks.

Very long range predictions (6 months) might be required for certain events such as break-up, freeze-up, and oil spill response.

Features represented should included, as required, some or all of the following:

- Landforms (for position of references).
- Open water (leads, polynyas, etc.).
- Ice type (first-year, multi-year, bergs, etc.).
- Ice conditions (ridged, rubbled, under pressure, etc.).
- Fixed hazards (shoals, reefs, etc.).
- Synoptic weather, sea state.

Detail and Accuracy: Strategic information presents an overview of conditions i.e. "the big picture". Fineness of detail and relative positional accuracy are therefore not critical, and a level of resolution equal to 1% of full range is suggested as being appropriate. Intrinsically fine detail such as ridges, icebergs, etc., would, if necessary, be represented schematically and characterized statistically using for example, WMO "egg codes".

Timing: "Nowcasts" and a range of forecasts are required. A now cast is a best estimate of conditions at the time of information release, based on the most recently available data. Since some of the latter may be several hours old when received for processing, an element of prediction might be required for nowcast preparation.

Ice forecasts will be generated by automatic processing of some or all of the following data types:

- Present ice position and velocity
- Present and predicted wind velocity
- Present and predicted ocean currents,

using a mathematical model. Actual forecast lead times would be dictated by user requirements, and might be constrained by practical limitations on the time available for computation. These constraints would be hardware dependent and cannot be evaluated at this point.

4.2.2 Tactical Information

General Description: Tactical information covers situations which are expected to occur within a day. It is anticipated that the specific features represented would be the same as in the strategic case. For the drillship example, the corresponding range would be 50 km, and the information would be utilized to initiate ice management activities such as icebreaking and iceberg towing, and to establish alert status.

For the Class 10 tanker example, a day's range would be typically 500 km. Course changes to avoid major ice obstacles or to take advantage of significant leads, would be based initially on tactical information, with or without route optimization.

Detail and Accuracy: Tactical level information must describe ice characteristics in detail sufficient to permit operational assessment of situations and to assist in response planning. Fine image-like detail is not required and, as for the strategic case, a level of resolution equal to 1% of full range is deemed appropriate. Keeping in mind that, for the tactical case, the overall range is much smaller than it is in the strategic case, the 1% criterion will permit the display of correspondingly finer detail. Note that some significant features, such as long ridges, may still be too fine to show up on such scales. In those cases, some form of schematic indication would be necessary.

Timing: As for strategic information, nowcasts and forecasts are required. Since the tactical time span is of the order of a day, 12 and 24 hour forecasts would probably suffice, with updates as required to take changes, for example weather forecast changes, into account. There is of course nothing to preclude more frequent forecasts should they be deemed necessary.

4.2.3 Close Tactical Information

General Description: This level of information deals with situations which must be handled within an hour or two.

For the case of drillships, the close tactical range would extend to 5 km whereas for the Class 10 tanker it would extend to 50 km. Essentially all available information of significance should be represented at this level. Information for fixed sites should also include ice velocities, whereas this information would not be of great significance to a rapidly moving vessel.

Detail and Accuracy: Close tactical information supplements normal human perception in the following ways:

- By extending range when visibility is poor
- By extending range over the horizon
- By assisting in the identification of surface features

In order that there be continuity between visual information and supplementary close tactical information, features recognizable in one should be identifiable in the other. This implies that the levels of

resolution should be roughly comparable, say, of the order of a few meters.

Timing: Close tactical information must be available in near real time. Forecasts will not be required.

4.2.4 Route Optimization Information

General Information: The output of a route optimization process is a suggested course to be followed. It could be represented as a table of positions and associated course changes, or alternatively as a map overlay.

Detail and Accuracy: Optimized routes will be based upon strategic and tactical information as described in Subsections 4.2.1 and 4.2.2. Route accuracies should therefore be consistent with those components of each information package.

Timing: Since optimized routes are based upon a forecast element (i.e., conditions as they are expected to be when the vessel reaches each location on the route), the routes would be updated as frequently as forecasts are updated or whenever progress achieved by the vessel departs significantly from the schedule.

4.3 Utilization Scenarios

This section clarifies the Information Package concept by illustrating how ice information might be accessed and utilized in realistic situations. The illustrations are based on four hypothetical activities as follows:

- Arctic Class 10 tanker, en route from an offshore Beaufort Sea oil production and storage facility to a terminal in one of the Atlantic provinces.
- Type E resupply vessel, en route from Quebec City to Resolute.
- Arctic Class 4 supply vessel, McKinley Bay to an offshore production site at Tarsuit ($136^{o}11.5'W$, $69^{o}53'N$).
- Oil spill response in Barrow Strait, utilizing a Type E vessel for logistic support and various small craft for cleanup operations.

4.3.1 Arctic Class 10 Tanker

In this Subsection, three vignettes portraying the use of ice information for strategic, tactical, and close-tactical purposes are presented.

(a) Typical Strategic information scenario.

Date: July 31.
Location: Beaufort Sea loading terminal, prior to departure
Destination: Port Hawkesbury.

Request:

At an on-board colour graphics console, the user specifies a need for most recent map (or maps) of ice conditions along the proposed route (or routes).

Response:

A colour-coded image of the latest weekly regional ice chart is transmitted to the vessel and displayed at an on-board colour graphics terminal. The ice chart, before transmission, is brought up to date with any new ridge or ice cover data sent in by various local observers. This is the "nowcast" product.

The nowcasts for the regions along route show the following conditions:

- Open water or open pack first-year ice: Beaufort Sea, Amundsen Gulf, Prince of Wales Strait, Lancaster Sound, Gulf of St. Lawrence.

- Consolidated old ice cover with some cracks: W. Viscount Melville Sound.

- Very close pack (9+/10), predominantly old ice: Central and Eastern Viscount Melville Sound.

- Very close pack (9+/10), predominantly first-year ice: Peel Sound, Viscount Melville Sound along south coasts of Queen Elizabeth Archipelago, Barrow Strait.

- Close pack ice (5/10 to 7/10), first-year: Western Baffin Bay.

- Bergy Water: Baffin Bay, Davis Strait, Labrador Sea.

On-Board Interpretation:

Under nowcast conditions, there would be two areas of concern, i.e. the consolidated old ice in Viscount Melville Sound and the iceberg conditions in Baffin Bay, Davis Strait and Labrador Sea.

New Request:

At the on-board console, the user requests, in order, forecast regional ice conditions for 24, 48 and 72 hours for the problem areas.

New Response:

A mathematical forecast model is applied to the nowcast ice conditions together with other information including forecast wind and air temperature. The requested forecast maps are transmitted to the on-board colour graphics terminal and stored there for later reference. The following changes are noted:

(1) Over 24-hours, ice cover boundaries are slightly, but not significantly, changed.

(2) Over 48 hours the consolidated old ice in Viscount Melville Sound becomes very-close-pack. Ice concentration in Barrow Strait reduces from very-close-pack to open-pack first-year ice. The ice mass in Baffin Bay extends further eastward across the Bay as overall concentrations reduce slightly.

(3) Long-range 72 hour forecast not provided on this occasion due to unreliability of present forecast cata.

New On-Board Interpretation:
The ice of Viscount Melville Sound will probably be more mobile and more susceptible to lead development. The Parry Channel ice is in the process of disintegrating east-to-west and will open up Barrow Strait imminently. Local winds will probably expand the Baffin Bay ice pack.

Action Taken:
A route through Parry Channel is selected and the tanker heads for the Channel via Prince of Wales Strait.

(b) Typical Tactical Information Scenario:

Date: August 2.
Location: Off Princess Royal Islands in Prince of Wales Strait.

Local Ice Conditions:
Six-tenths cover of unridged first-year floes. Most floes are of 500m to 700m diameter; two floes of 1500m diameter are in immediate vicinity. Ice floe thickness is 1.8 m to 2.0 m.

A request for SAR support results in SAR reconnaissance of Parry Channel, with data being downlinked directly to vessel.

The conditions are determined to be as follows:

- Western end of Viscount Melville Sound is consolidated with two refrozen cracks in the centre (grey-white ice). Concentration otherwise is as per regional reconnaissance interpretation; proportion of multi-year to second-year ice increases gradually toward the east end of the Sound. A narrow coastal lead shows up next to Dundas Peninsula of Melville Island. Moderate ridging is indicated at the old ice boundary south of Melville Island.

On-Board Interpretation:
Boundaries drawn between multi-year and second-year ice in Viscount Melville Sound; problem ridge areas identified.

Action Taken:

Ice breaking course is set through the western end of Viscount Melville Sound such that multi-year ice floes are circumvented. The route takes the shortest feasible way through second year ice to the refrozen leads, thence across any other second year cover, through the least formidable ridge area possible, and into the first-year ice and lead off Dundas Peninsula.

(c) Typical Close Tactical Information Scenario:

Date: August 7.
Location: Central Lancaster Sound.
Local Ice and Weather Conditions: Open water with heavy fog.

Ship's radar, at 12-mile range, low sea-clutter-suppression setting, displays cluster of echos 3 miles off starboard bow. Impact felt on starboard bow.

On-Board Interpretation:

Previously unreported/unforecast cluster of icebergs encountered, along with undetectable growlers. Position of icebergs along with any other descriptive information will be transmitted in message format to REMSCAN Central along with request for updated tactical information.

Action Taken:

Speed reduced as drift trends of icebergs are noted on ship's radar. Helm put over to port slightly, away from icebergs under assumption that icebergs will depart the Sound along the south (starboard) coast, as per historical observation.

4.3.2 Type E Resupply Vessel

Again, ice information utilization is portrayed using three vignettes covering the strategic, tactical, and close-tactical situations.

(a) Typical Strategic Information Scenario

Date: 12 August
Location: Quebec City, prior to departure

Destination: Resolute Bay (and return)

Request:

Through radio frequency voice link, user specifies need for most recent map of ice conditions along the proposal route.

Response:

The vessel receives a black-line facsimile copy of the latest regional ice chart as a paper copy from on-board facsimile

receiver. Prior to transmission, the chart is updated with any new iceberg and ice cover data sent in by various local observers. This is the "nowcast" product.

The following conditions appear of the typical nowcast chart: Ice free water: Lower St. Lawrence, Gulf of St. Lawrence, Strait of Belle Isle, southern Labrador Sea.

- Open water with icebergs: northern Labrador Sea, Davis Strait, eastern and northern Baffin Bay, eastern Lancaster Sound.

- Open water with occasional sea ice remnants: western Lancaster sound, northern Barrow Strait into Resolute.

- Sea ice pack of 3/10 to 9/10 concentration, with as much as 2/10 multi-year ice, off the east coast of Baffin Island and extending half-way across Baffin Bay.

On-Board Interpretation:
Under nowcast conditions, the one concern would be icebergs along the route between Labrador Sea and Lancaster Sound. The Baffin Island pack would be impenetrable to the vessel.

New Request:
The user requests a 72-hour ice forecast via the radio link. The 24 and 48 hour forecasts would be of little interest as only ice free waters would be travelled in that time.

New Response:
A mathematical forecast model is applied to the nowcast ice conditions. The requested forecast map is transmitted to the on-board facsimile receiver as a black-line paper copy.

Forecast shows contraction of the Baffin Island pack and eastward displacement of Barrow Strait ice floes into the open water route to Resolute.

New On-Board Interpretation:
Sea-ice conditions over-all tend to be improving. The last leg, into Resolute, is experiencing ice incursions due to decay and dispersal of ice in channels further to the west.

Action Taken:
Course set for Resolute Bay via Strait of Belle Isle and standing out toward Greenland in order to avoid Baffin Island ice pack.

(b) Typical Tactical Information Scenario

Date: 21 August
Location: Northern Baffin Bay

Local Ice Conditions:
Open water with icebergs in vicinity. Visual contact maintained. Fifteen miles visibility.

On request, an ice reconnaissance map, based on a SAR flight earlier that day, is transmitted to ship's facsimile receiver. Conditions are as follows:

Last 50 miles of open water to Resolute now occupied by 6/10 concentration of predominantly thick first-year ice floes drifting southward out of Wellington Channel. Floes are generally unridged, 3 m thick, and 100-500 m in diameter.

On-Board Interpretation:
The last 50 miles may require patience.

Action Taken:
Course unchanged. Vessel proceeds into Lancaster Sound towards the western limit of open water.

(c) Typical Close-tactical Information Scenario

Date: 24 August
Location: off SW tip of Devon Island

Local Ice Conditions:
Vessel in open water with 3/10 concentration of thick first-year floes in sight immediately west.

Information:
Visual survey, from bridge, of route ahead reveals some thick multi-year floes among the 3/10 first-year cover. Definite floe displacement is discernible.

On Board Interpretation:
Floe size and movement will make transit unduly hazardous despite relatively low ice cover.

Action Taken:
Wait in open water until ice conditions in route attain safe proportions.

4.3.3 Arctic Class 4 Supply Vessel

In this scenario, the distinction between strategic and tactical requirements blurs, and a single vignette describing both situations is presented. Note that information of an unambiguously strategic nature would presumably have been utilized previously by logistics planners in scheduling the voyage and other preparatory activities.

A separate vignette is used to portray the close-tactical situation.

(a) Typical Strategic/Tactical Information Scenario

Date: 10 January
Location: McKinley Bay, prior to departure

Destination:
Offshore production facility at Tarsiut (and return)
Because the area of transit is restricted, strategic and tactical information will be one and the same.

Request:
At an on-board graphics console, the user calls up the appropriate segment of the most recent SAR-based interpreted ice chart.

The information received reveals the following:

Moderate to heavy ridging ten miles north of McKinley Bay anchorage. Thin first-year ice (60 cm) over most of route with an average two ridges per kilometre greater than 0.5 m height; 0.2 ridge per kilometre greater than or equal to 1.5 m height. Production facility is five miles west of landfast ice outer boundary, in thin first-year ice with four small floes of second-year ice within five miles to north. Ice at site has moved west leaving a 25 mile wake of new to grey-white ice to the west.

On-Board Interpretation:
Ridges at entrance to McKinley Bay may slow down the first part of the transit. The second-year floes near Tarsiut could be avoided.

Action Taken:
Attempt begun to exit McKinley Bay via existing dredged channel. Thereafter, route to be the most direct through thin first year ice.

(b) Typical Close Tactical Information Scenario

Date: 13 January
Location: 10 miles northeast of Tarsiut

Local Ice Conditions:
Thin first-year ice.

Information:
Radio report from Tarsiut informs vessel that wake to west has closed subsequent to southward movement of local ice sheet. New wake has appeared on south side of facility and two second year floes are now 3 miles north of site.

On-Board Interpretation:
Approach to site will be easier if made from south.

Action Taken:
Southwesterly course set to bring vessel round the southeast point of the facility and into the new wake.

4.3.4 Oilspill Response

This scenario illustrates the way in which REMSCAN could serve the needs, some of them highly specialized, of a response to an oilspill in the Barrow Strait.

Event: Tanker collision with another transport vessel resulting in spill of crude oil cargo
Date: 20 August
Location: Eastern Barrow Strait near entrance to Wellington Channel

Ice Conditions:
1/10 concentration of first-year floes, 100 m and less diameter; strips and patches of 6/10 concentration including 1/10 multi-year; open water immediately to east, in Lancaster Sound

Weather and Sea:
Strong northwesterly wind; light sea conditions, moderate seas to east in Lancaster Sound.

Magnitude of spill:
135,000 barrels spilled in 4 hours.

Request #1:
On-scene commander requests transmission of latest regional ice chart and forecasts to response vessels.

Response:
REMSCAN Central transmits requested information to video display terminals or facsmile receivers aboard designated vessels. If chart reproduction facilities are not available on some vessels, key ice navigation data is forwarded via voice link.

Data Transmitted:
An open water route exists between the spill site and all points on Baffin Island and the east coast although icebergs may be encountered in Baffin Bay and eastern Lancaster Sound. Nine-tenths and 9+/10 ice covers exists through Viscount Melville Sound, evenly divided between old floes and thick first-year ice. The southern passage via Peel Sound or Bellot Strait is mostly open water with some 2/10 concentration in Larsen Sound and Prince Regent Inlet.

Action Taken:
Necessary response vessels not already in the vicinity of the spill are despatched via Lancaster Sound (from east coast) and via Queen Maud Gulf (from Beaufort Sea).

Request #2:
On-scene commander requests that data output from oilspill computer models be transmitted to response vessels and to oilspill response field headquarters being established at Resolute.

Response:
REMSCAN Central runs the required programs using up-to-date environmental data inputs. Graphics, such as forecast spill trajectories, are transmitted to field units served by monochrome display terminals. Numerical output is transmitted to a remote printer at field headquarters and to response vessels equipped to receive such output. Other units receive a verbal/numerical summary of model results via voice link or teletype system.

Data Transmitted:
Spill is forecast to arrive on the north coast of Somerset Island on 23 August with 25 to 50% of original oil content.

Action Taken:
SAR flight planned in order to ascertain geographic extent of the spill.

Request #3
SAR flight requested.

Response:
SAR hard copy is transferred from SAR airplane to user upon landing at Resolute.

Data Acquired:
A 300 km^2 slick is shown immediately south-southeast of the collision site and extending approximately 25 km in that direction. A patch of 6/10 ice cover, 100 m floes, partially blocks the spill to south.

Action Taken:
Dispersant flight planned and dispatched while spill remains over deep water. Map drawn from SAR and dispatched to field units.

Note: It is assumed that surface units (response vessels) are simultaneously carrying out, or arriving at site to carry out, pumping operations on remaining oil cargo.

5.0 REMSCAN Conceptual System

This Part is intended to describe REMSCAN conceptually in terms of the functions which it must perform in order to provide the information described in Part 4.0. Functional elements and subsystems are defined, as a logical first step in system design. Although a functional description leads naturally to a description of the system in terms of actual components, discussion of design detail is excluded from this part. Examples of straightforward technologies may however be used to clarify various aspects of the concept.

5.1 Definition of REMSCAN

REMSCAN is primarily an ice information system. Within the limitations on scope described in Section 5.2, it comprises a functionally integrated set of:

- Planning methods
- Data acquisition means
- Communications channels
- Information processing and analysis means
- Management methods

for providing ice-related information throughout Canadian coastal waters and the approaches thereto to serve the needs of vessels and fixed-site offshore activities. The specialized needs of oil spill response activities are also addressed.

5.2 System Scope

It is necessary to restrict the scope of REMSCAN in order to:

- Accomodate user preferences and priorities
- Live with fundamental technical constraints
- Maximize cooperation with and utilization of other existing and planned systems and organizations.

The following assumptions have therefore been made:

a) Sensors will, under most circumstances, be owned, operated, and maintained by the users as part of their normal complement of navigational or hazard detection instrumentation, over which most users wish to maintain control. In some cases, where data essential for carrying out REMSCAN functions might not be available when and where required, REMSCAN might have to operate some of its own sensors (e.g. SAR) or, at least, direct the attention of privately operated sensors.

b) REMSCAN will not address the close-tactical needs identified in Part 4.0. The range of user needs and preferences is widest at this level, creating a need for great information diversity precisely where detail is most significant. This results in a major limitation being imposed by the availability at reasonable cost of communications channels with sufficient bandwidth.

c) REMSCAN will provide "dynamic expansion" of on-board ice sensing capability as required. The availability of REMSCAN could, on suitably equipped vessels, be equivalent to having a "smart" radar with extra range switches and interpretive capability, or to having a dedicated weather and ice advisory service via message or facsimile.

d) REMSCAN will be upwardly compatible with new technology. REMSCAN-provided information will be limited ultimately by the capabilities of the sensors in use. As improved sensors become available, REMSCAN will utilize the new information with, at most, minor technical changes to accommodate new data formats, etc.

5.3 Basic Functional Concept

A system capable of generating the Information Packages described previously must carry out four major functions, as follows:

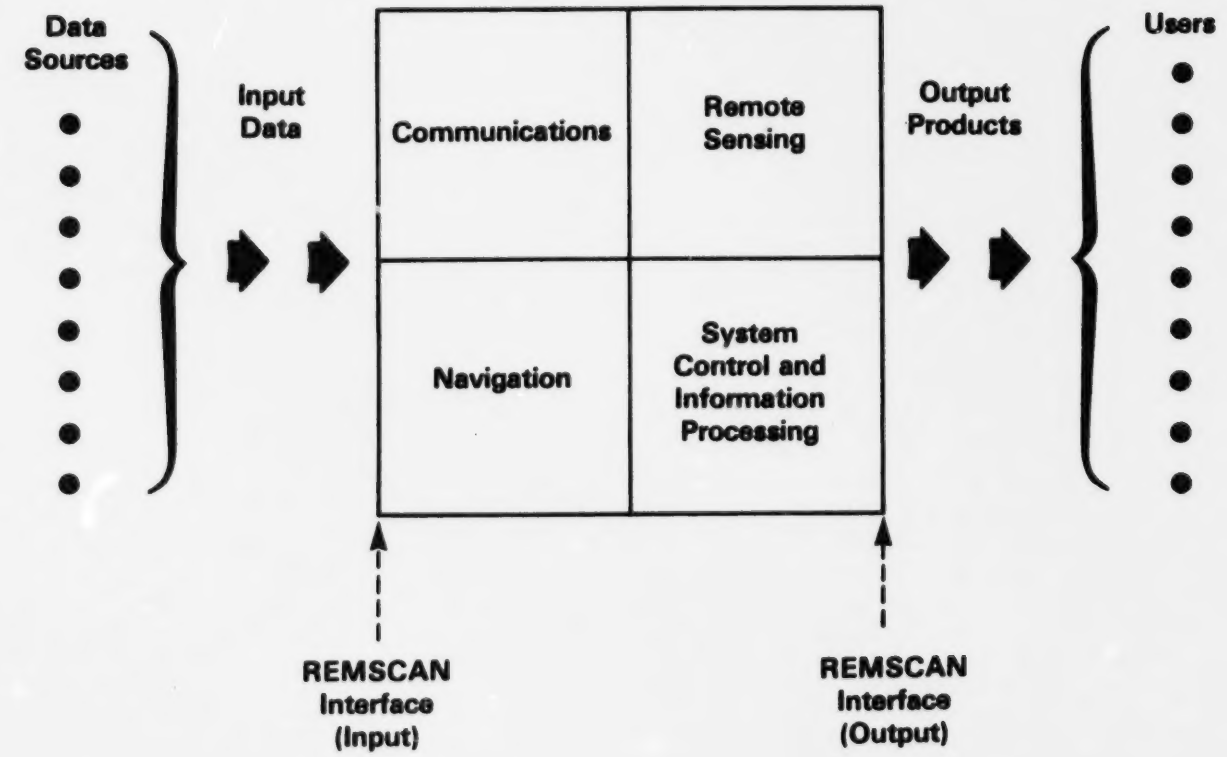
- Capture data, imagery, and other information on ice and related environmental quantities.
- Capture positional information in order to relate the positions of ice features and user locations to standard maps and charts.
- Process the data into usable and desirable forms as described.
- Communicate data and processed information among users, participating organizations, and central processing facilities.

5.4 Functional Block Diagram

A functional block diagram of the REMSCAN concept is shown in Figure 5. Again, design details are specifically excluded since alternative means of implementing this concept are contained in other sections of the report. Definitions and descriptions of the REMSCAN subsystems are provided later; however, points important for interpretation of the diagram are reiterated as follows:

- REMSCAN does not normally include the Data Sources but will specify those input requirements which are essential to achieve the desired output.
- REMSCAN Interfaces must accept a wide range of data types (from (say) imagery to HF radio voice).
- REMSCAN Communications are limited to communicating within the REMSCAN block, inclusive of the interfaces.

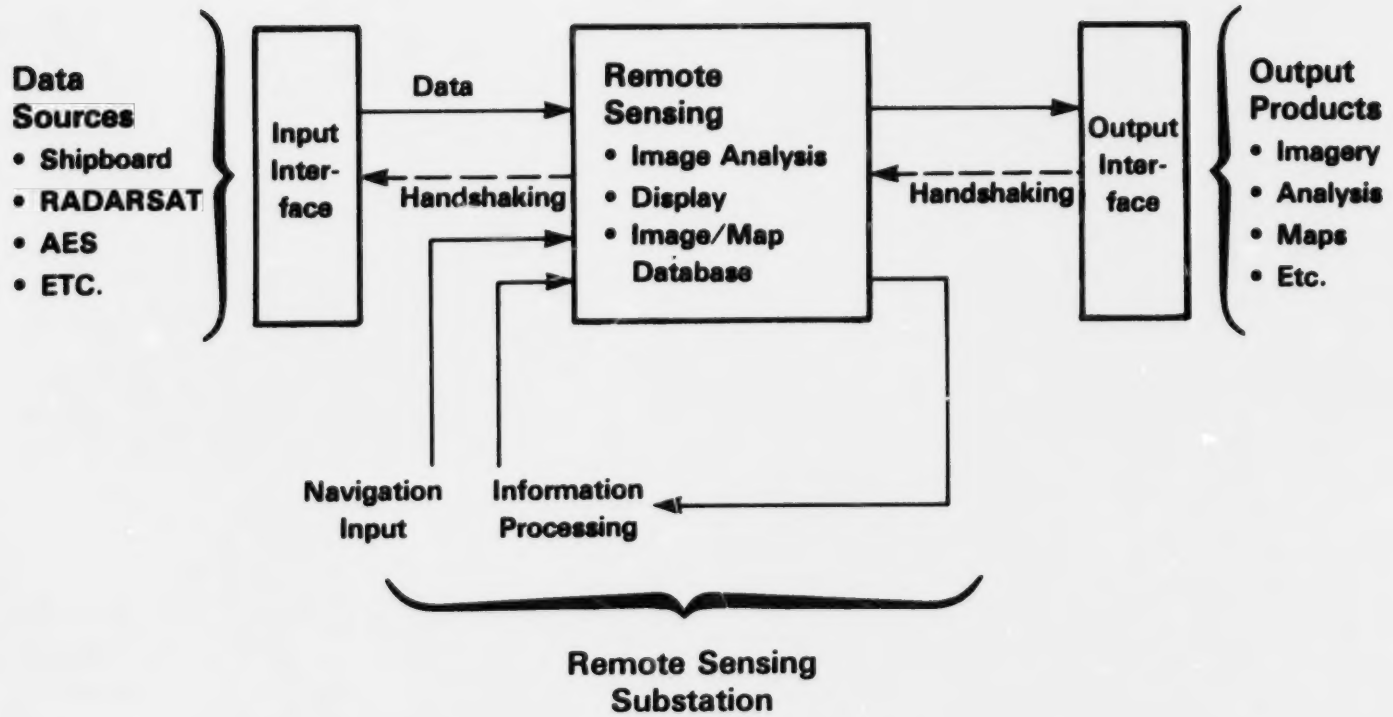
Functional block diagrams of major REMSCAN sub systems are shown in Figures 6, 7 and 8. At this point, it is important to emphasize that the system concept is portrayed in functional terms only. When implemented, the functional illustration would not necessarily portray actual system architecture or hardware configuration. For example, the subsystems are described in terms of separate, parallel functions even though the design implementation might be based on distributed processing and a vertically integrated data base. It is not intended that this conceptual phase address alternative means of implementation.



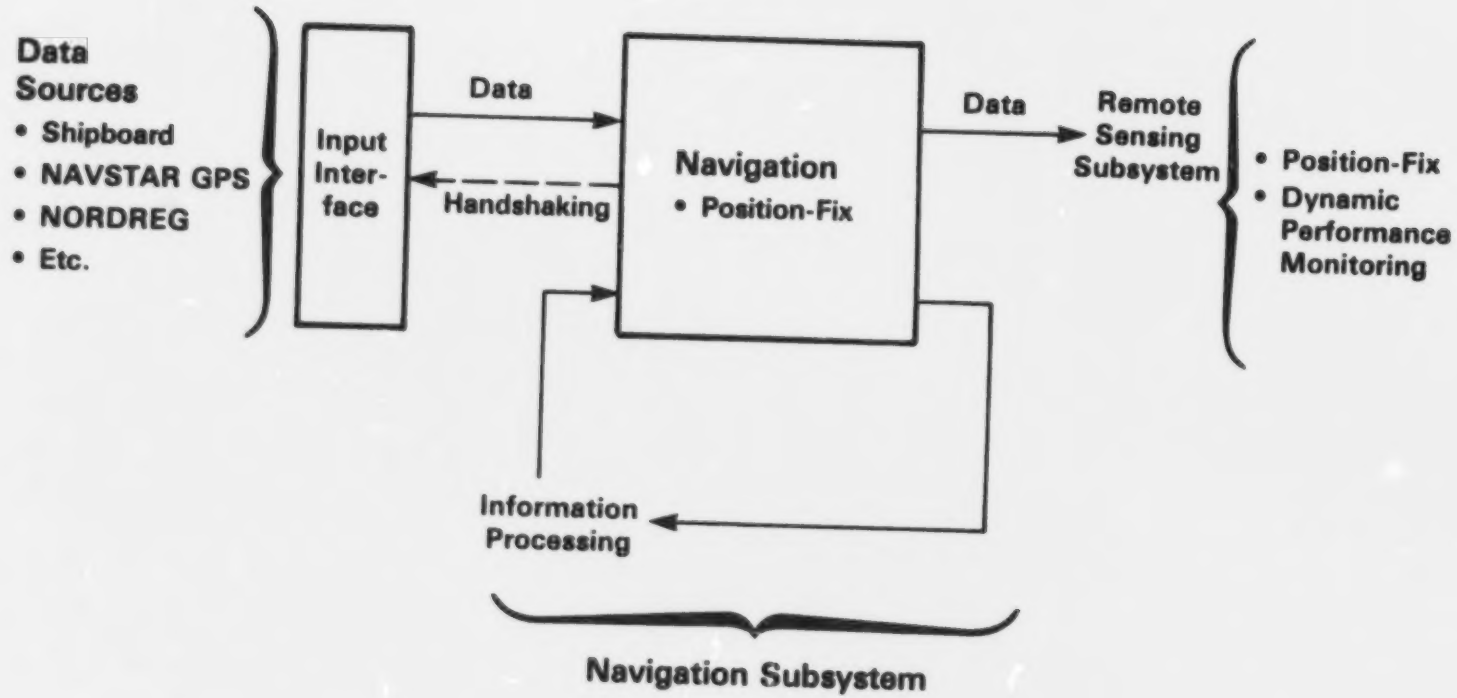
CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN FUNCTIONAL CONCEPT FIGURE No. 5

To facilitate a complete understanding of the REMSCAN concept, it is worth considering examples of typically complex sequences of operations. Referring to Figures 6, 7 and 8, consider the case of two ships subscribing to REMSCAN; one (Ship A) is equipped with a satellite terminal for high speed data and the other (Ship B) is equipped only with HF radio. Both vessels have requested ice situation reports and forecasts for particular regions in order to identify potential ice hazards which might cause them to take evasive action. It is assumed that REMSCAN has been in operation for sometime and prior to the ships' requests for information, the Remote Sensing subsystem will have been collecting data from sources such as airborne SAR, Radarsat, shipboard sensors, and, meteorological observation and forecasting agencies.

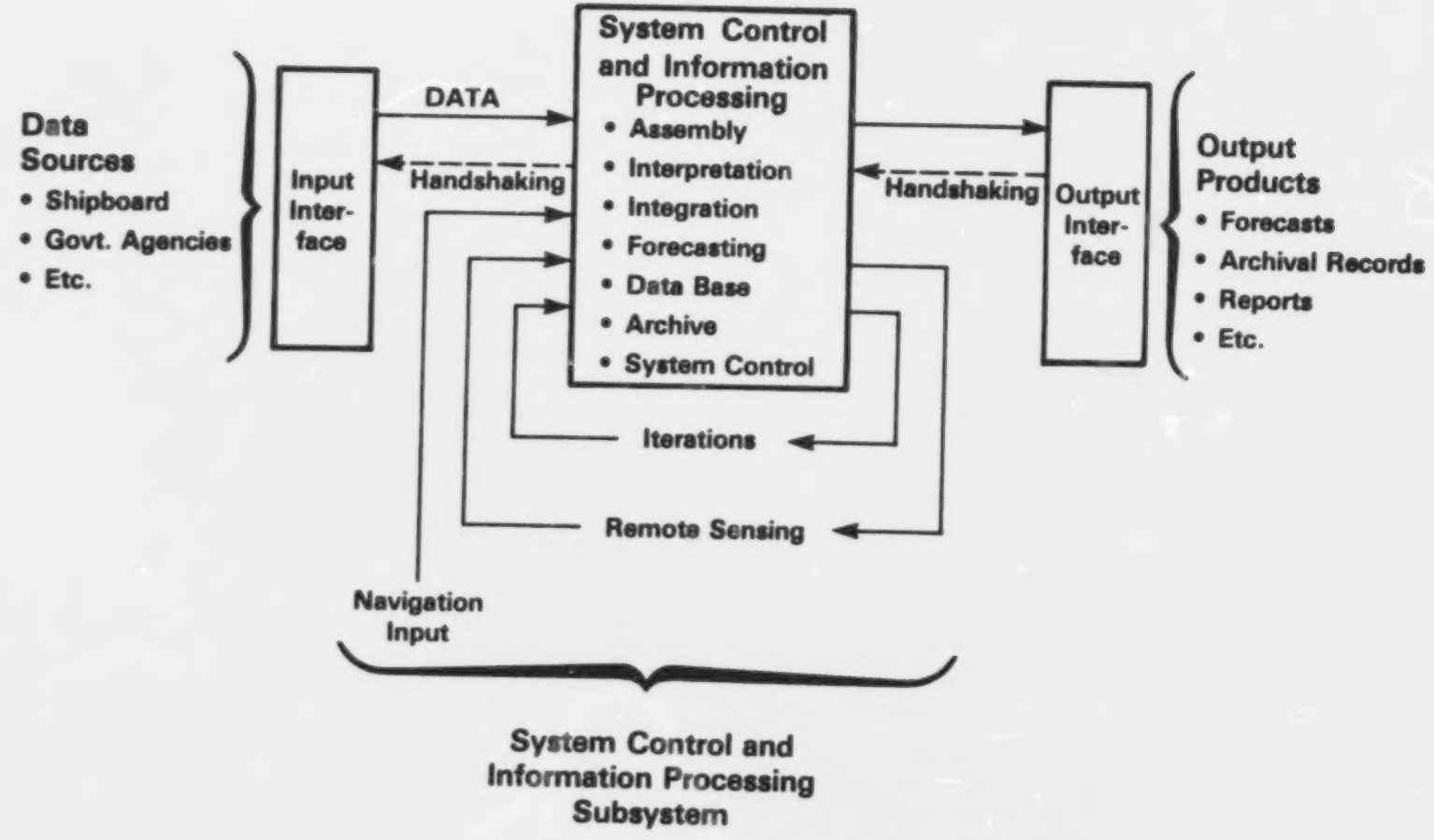
Operation	Ship A	Ship B
1. Request	Entered menu-driven format at color graphics console, (input interface), transmitted via satellite to REMSCAN Central	Called into REMSCAN interface using HF radio voice or formatted message
2. Task Assignment	System Control receives request, assigns task to Remote Sensing subsystem, archives request	same as Ship A
3. Processing	Remote Sensing calls up latest analysis of region, updates it with airborne SAR imagery if available, collates with visual reports from other transiting vessels, annotates ice hazards. Navigation subsystem provides NAVSTAR position-fix data for ice hazards.	same as Ship A
4. Forecasting	Formatted ice data transferred to System Control subsystem which runs forecast based on historical (observed) data, climatic trends, weather forecasts and dynamic modeling. Route optimizer models ship progress using known ship parameters. Movement vectors produced and sent to Remote Sensing subsystem	same as Ship A



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: FUNCTIONAL REMOTE SENSING SUBSYSTEM
		FIGURE No. 6



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: FUNCTIONAL NAVIGATION SUBSYSTEM
		FIGURE No. 7



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: FUNCTIONAL SYSTEM CONTROL AND INFORMATION PROCESSING SUBSYSTEM FIGURE No. 8

5. Output Product Composition	Output interface advises REMSCAN that Ship A can receive colour graphics via satellite channel. Remote Sensing subsystem composes color coded charts depicting ice hazards and predicted movement	Output Interface advises REMSCAN that Ship B can receive HF radio. Remote Sensing subsystem composes charts and text of ice hazards, positions, and predicted movement
6. Distribution	Output Interface searches for suitable satellite channel, establishes link for sending data to ship, text copied to ship's company head office	Output Interface searches for suitable HF channel, transmits charts over facsimile, text by voice, copied to company head office
7. Display	Color graphics terminal displays various charts called up from local storage	Facsimilied charts and text used as is
8. Archiving	System Control obtains from Remote Sensing portions of transaction to be archived	Same as Ship A

5.5 Functional Subsystems

There are four REMSCAN Subsystems: (a) Remote Sensing (RSS), (b) Communications (COMSS), (c) System Control and Information Processing (SCIP) and (d) Navigation (NAVSS). Other related systems such as RADARSAT or MSAT are services which a REMSCAN subsystem may utilize or interface with, but are not in themselves part of the REMSCAN system or any individual subsystem.

5.5.1 Remote Sensing Subsystem

The remote sensing subsystem comprises the means by which capture and specialized processing of remote sensing imagery from all necessary and available imaging sensors such as shipboard or airborne radars, are carried out. This subsystem would normally exclude the sensor and any associated front-end processing and telemetry that might be used for translating raw data into formats suitable for real-time display, communications, and distribution outside the REMSCAN interface. The RSS would however specify the types of sensors required to provide data necessary for the production of output products. For example, RADARSAT is considered to be a remote sensing device (sensor), and therefore not a part of REMSCAN. The RADARSAT output, however, might be compatible with or made compatible with REMSCAN to become an input source for utilization and distribution therein. On the other hand, where a particular remote sensing requirement were not being met by external services, the REMSCAN infrastructure would have to provide the

capability. The RSS is predominantly a means of selecting, capturing, and processing imagery. The functions of this system would be as follows:

- Select and acquire data from imaging sensors (topographic, bathymetric, etc.)
- Interpret imagery
- Display topographic ice information
- Perform image analysis functions such as image correlation and pattern recognition
- Provide automatic and semi-automatic (operator interface) tracking
- Receive continuous feedback from forecasting function of the information processing subsystem.

5.5.2 Communications Subsystem

The COMSS consists of the means by which pre-processed and compatible data are transferred from point to point within REMSCAN for compilation, processing and distribution, and those communications necessary to serve REMSCAN-provided data sources. The COMSS might comprise special-purpose communications and might utilize (and specify requirements for) common carrier and private services for the flow of data between the REMSCAN interfaces. For example MSAT or conventional HF circuits might be used by the REMSCAN system but would not themselves be components. Also, the RADARSAT downlink would be used to acquire data for eventual input to REMSCAN but would not be considered part of the COMSS. If an interface were required to translate (for example) RADARSAT imagery to a REMSCAN compatible form, the interface would be part of the REMSCAN system.

The REMSCAN COMSS is responsible for distribution of data and information between the REMSCAN input and output interfaces. As a result of the wide range of data types that the interfaces must contend with, the complexity of the communications facilities will be inversely proportional to that of the interfaces. It is expected that the interfaces will reduce the range of communications requirements to a minimum which will be predominantly within the capabilities of common carriers. This would reduce the requirement to develop special-purpose facilities and thus the communications problem would become one of managing commercially available resources. The object of constraining the REMSCAN COMMS to the interface boundaries is to establish manageable limits as well as to afford flexibility to users. Offshore users, for example, can subscribe to what they determine to be their most cost effective mix of communications and REMSCAN services consistent with the requirement for quality ice information. The functions of the REMSCAN COMSS are:

- Allow efficient and timely distribution of data within interface boundaries (including any near real-time requirements)
- Service REMSCAN interfaces and subsystems
- Maximize throughput by utilizing signal processing, compression techniques etc.
- Be transparent to users and data sources
- Handle all data types dictated by REMSCAN interfaces and subsystems

- Utilize commercial carriers wherever possible
- Provide high grade of service, reliability, and availability
- Incorporate redundancy, alternate routing, and graceful degradation
- Be location independent; that is, communications subsystem (like information processing) may extend to user locations (for example, vessels) depending on location of interfaces.

5.5.3 Navigation Subsystem

The NAVSS comprises the means by which navigation and position-fix data are acquired and used in conjunction with other REMSCAN subsystems, notably RSS and SCIP. Like the RSS, it would not normally include site-specific (e.g. shipboard) components which are integral to the vessel's navigation capability, but might specify the types of data sources required to produce the required REMSCAN products. Site-specific data would be acquired by the NAVSS (via the input interface) for integration with other position-fix and remote sensing data. For example, position data obtained from (say) shipboard sensors and GPS NAVSTAR (both external systems) could be combined with data acquired by the RSS, to produce a Warning to Mariners of particular ice obstacles. If a particular position-fix requirement were not being met by an external system, the REMSCAN infrastructure would have to provide for it.

The functions of the REMSCAN NAVSS are as follows:

- Obtain real-time navigation and position-fix data.
- Provide data to SCIP and RSS
- Provide position-fix capabilities not met by external facilities.

5.5.4 System Control and Information Processing Subsystem

The SCIP subsystem consists of those means by which system functions and timing are coordinated and by which data and information, other than that serviced by the RSS or NAVSS, are assembled, manipulated, and disposed. This subsystem would evaluate input data and provide reaction times consistent with the needs of the user, in real-time or near real-time as required. When implemented, some functions of this subsystem might overlap or be shared with the other REMSCAN subsystems; however, from a conceptual perspective, they are separate. For example, data acquired from shipboard sensors could be telemetred directly to the SCIP subsystem and immediately switched (without processing) to another user. The role of the SCIP subsystem would in this case be to instruct the input interface to poll the sensors (to acquire the data), to receive the data, and to evaluate them to determine any need for further processing. The COMSS would simply be the medium by which data would be transferred between interfaces or among REMSCAN subsystems.

REMSCAN information processing is limited to that processing, manual or automated, which is performed between the REMSCAN input and output interfaces. Information processing consists of five operations as follows:

- Assembly which is the reduction of information to standardized and usable forms and its arrangement in groups of related items
- Evaluation which is the determination of the pertinence, reliability and accuracy of the information and the elimination of non-essentials
- Interpretation which is the determination of the significance of the information and the drawing of conclusions as to probable meaning and implications
- Integration which is the collation of interpreted information with other data to confirm, validate, or update
- Archiving which is the recording of non-volatile information.

System control comprises those functions necessary to:

- Acquire data on a timely basis
- Sequence processing functions and transfers of data and information between REMSCAN subsystems
- Maintain system files/data bases
- Service user requests.

5.5.4.1 Integration

The integration of data sources is one of the primary advantages of the REMSCAN concept. The reasons for integration are:

- To overcome the limitations of individual data sources and sensors by using complementary technologies
- To produce a synergistic effect with information collected from one source being used to improve the quality or quantity of another
- To avoid unnecessary redundancy in numbers and types of data sources and collection systems, while ensuring adequate coverage of regions
- To enable all users to receive adequate support within REMSCAN-serviced regions to a degree commensurate with their capability

5.5.4.2 Forecasting/Modeling

As well as the purely data processing and control functions, the SCIP subsystem will support various forecasting and modeling capabilities utilizing observed (and externally-forecast) data to produce forecasts for user groups. The types of models to be included are:

- Fine Scale Ice forecasting
- Regional Ice Forecasting
- Weather/Oceanographic Forecasting
- Vessel Performance Modeling
- Vessel Traffic Simulation/Route Optimization
- Oil Spill Modeling

The forecast-related functions of the SCIP subsystem are summarized as follows:

- Assemble, evaluate, interpret, integrate, archive and distribute data
- Incorporate forecasting and modeling capabilities
- Provide manual and automated access to information and processing operations
- Maintain timely flow of data
- Ensure adequate level of backup for manual and automated operations
- Provide for graceful degradation of information processing capabilities in the event of malfunctions
- Provide for distributed processing capability

5.5.4.3 Relationship to Remote Sensing Subsystem

Data acquired from airborne or shipboard imaging sensors and processed by the RSS would be retained therein in an imagery/map data base along with RADARSAT and AES-generated imaging and charts. The role of the SCIP subsystem in regard to imagery would be to maintain a catalogue of the imagery available on file, to prepare forecast maps for inclusion in the imagery/map data base, to maintain continuity of coverage through monitoring of the age of the data base contents, and to determine when updating is required. The forecasting function would be based upon maps produced by the RSS and upon a separate, SCIP subsystem data base containing non-image information.

The imagery/map catalogue would be made available to the output interface.

5.6 Data Sources

A data source is any sensor, group of netted sensors, agency, service or system which provides weather, sea, ice, position-fix or performance monitoring data relevant to the REMSCAN information system. Data sources would not normally be part of the REMSCAN system. However REMSCAN would specify the types of data and data sources required to produce the necessary output products.

As stated earlier, the REMSCAN System would not normally include sensors or any pre-processing integral to them. On the other hand, REMSCAN would specify the type of sensor required to provide data necessary to produce the various outputs requested by users. Data sources are noteworthy due to their number and to the diversity of input media which will have significant impact on the REMSCAN implementation parameters. The wide range of potential data sources adds to the complexity of interfacing, communications and processing. Further, the number of sources is expected to increase as technology progresses, as space-based systems proliferate, and as traffic and the number of users expand. REMSCAN is to be upwards compatible with all future data sources. A list of representative data sources is as follows:

Shipboard
- Navigation/anti-collision radars
- Digital radar
- Visual OBSERVATIONS (aided and unaided)
- Tactical reconnaissance (airborne/attending vessel)

- Dynamic performance monitors
- Situation reports
- Sonar
- Meteorological sensors

Airborne
- SAR/SLAR
- Visual
- Other remote sensing (fluorosensor, profilometer)
- IR scanners
- Impulse radar and related devices

Land Based

- Sensors (oceanographic, meteorological)
- Support bases
- Harbour reports
- Government/civil agencies (CCG, AES, DND, COGLA, DIAND, C-CORE, etc.)

Space Based
- RADARSAT
- ARGOS/NOAA
- GPS NAVSTAR
- Scanning Multichannel Microwave Radiometer
- LANDSAT

Other (REMSCAN Internal)

- Navigation subsystem
- Communications subsystem
- Organizational infrastructure
- Forecasting

Other (External)
- Oil/gas industry (offshore platforms)
- Fishing vessels
- Foreign vessels

The functions of the data sources would be as follows:

- To provide raw data or pre-processed information to REMSCAN
- In some cases to act in a dual capacity to display output products
- To provide real-time (pre-REMSCAN) information of a close-tactical nature to users

5.7 Output Products

The output product is simply the information or deliverables which REMSCAN produces, based on the needs of users. The composition of the output product would be constrained by two factors: firstly, by the type of information which is produced (e.g., map, text, imagery, etc.) and secondly, by the medium by which the user is capable of receiving it

(e.g., HF radio, wide-band data link, etc.). For example, whether a user would receive the information in digital form displayed on CRT, or receive it by facsimile over HF radio would depend on the user's technical capability as well as upon the information itself. The REMSCAN system concept provides for the full range of output products to be delivered to users via diverse media.

As stated above the output product is constrained by two factors: firstly, the product itself, as defined by the user; secondly, the medium by which the product would be transmitted (which would vary depending on the user and the product itself). A partial list of media by which output products could potentially be distributed is as follows:

Shipboard
- Radio voice (MF, HF, VHF)
- Facsimile
- Commercial carrier (telex, telephone)
- Data link
- Aircraft overflights
- Satellite terminal
- Downlink

Fixed Offshore Platforms
- As for shipboard
- Single frame video
- Postal/courier
- Meteor burst

Land Based Agencies
- As for Fixed Offshore Platforms
- Video (television)

The output products will be diverse in type and quantity of information and must be compatible with a wide range of communication and display media. The single function of the output product would be:

- To provide information to users

5.8 REMSCAN Interfaces

There are two REMSCAN interfaces, one input interface and one output. The input must accept data from all data sources and translate them to forms compatible with the REMSCAN subsystems. The output interface would translate REMSCAN output products into forms compatible with the range of external media available to service users. The interfaces embody protocols to perform the necessary format conversions but would also, contain sufficient processing capability to establish continuous handshaking functions among data sources, users, and REMSCAN subsystems. Due to the wide range of communications media for transmitting data to and from REMSCAN, the interfaces might consist of many component types distributed throughout the system. From a conceptual point of view, however, there would be only two interfaces.

Furthermore, the input and output interfaces would be limited to transferring information between REMSCAN and external data sources and users. Any internal communication among REMSCAN subsystems would be achieved either by compatibility of design or by the communications subsystems as required.

The REMSCAN interfaces would comprise organizational, procedural and technical means, both automated and manual, with which REMSCAN subsystems would acquire data (input interface) and distribute information (output interface). The input interface would translate data from diverse types of data sources gathered via a wide range of communications media, into formats which are compatible with the REMSCAN system. Conversely, the output interface would translate REMSCAN output products into formats suitable for transmission to users over a variety of media. The interfaces must have sufficient 'intelligence' to continually update REMSCAN subsystems as to the nature of data sources and users, and as to the users' abilities to send and receive information respectively. This function is referred to as handshaking. For example, it would be the output interface which would determine that a particular vessel could only communicate via HF radio and moreover had no colour graphics capability. The interface would so inform REMSCAN subsystems and could ensure that output products were compatible, i.e. voice, text or facsimile, as appropriate, and not colour-coded charts. The input and output interfaces would be limited to interfacing REMSCAN with external systems and devices.

The functions of interfaces would be to:

- Allow orderly and timely acquisition of raw or pre-processed data
- Allow orderly and timely distribution of output products
- Package user-specific output product
- Translate data (input and output) to and from REMSCAN compatible formats
- Establish queuing hierarchies consistent with the importance and timeliness of data (input and output)
- Establish hand-off procedures for data sources and output product users transiting REMSCAN regions (if appropriate) and while entering or leaving REMSCAN serviced regions
- Ensure alternative means exist for handling input and output data through redundancy and organizational structure
- Maintain continuous handshaking between data sources and REMSCAN to ensure subsystems are aware of sensor characteristics
- Maintain continuous handshaking between users and REMSCAN to ensure subsystems are aware of output product transmission media appropriate to particular users.

Interface components would be distributed throughout REMSCAN as required.

6.0 DESIGN APPROACHES

Three distinct approaches to implementing the REMSCAN functions described in Part 5.0 have been identified as potential candidates for detailed analyses. These are referred to as:

- The Centralized Approach
- The Distributed Approach
- The Hybrid Approach

In this Part, these alternatives are evaluated and a recommendation is made.

6.1 Description of Alternative Approaches

The three approaches are described in this section, and their main characteristics are summarized in Table 2. It is noteworthy that all three approaches distribute the REMSCAN functions among the same set of elements, namely vessels, REMSCAN Central, and Regional Centres. It is the degree of autonomy conferred upon the individual locations which serves to distinguish the three approaches.

a) In the Centralized Approach, all image processing, analysis, interpretation, and forecasting functions would be carried out at a central facility to be located presumably in southern Canada. Field sites would require only data acquisition and display capabilities and would be serviced by long-range wide-band communications capable of transmitting imagery in near-real time. Skilled ice imagery interpreters would not be required in the field. This approach is close to the original REMSCAN concept.

b) In the Distributed Approach, the capability of individual field sites to acquire, process, and interpret all data, including airborne imagery, necessary to serve their own ice information requirements would be maximized. The central facility would be responsible only for communications between sites and for system housekeeping functions such as SAR aircraft scheduling and supervisory monitoring of vessels. It would maintain an overview of ice conditions commensurate with those tasks. Skilled interpreters would be required on board each vessel, and at each fixed site or cluster of sites. The integration and processing of regional data for strategic applications would be costly. This approach is closest to that being pursued by the M.V. Arctic.

c) The Hybrid Approach represents a compromise between the two other Approaches. The aim is to retain the advantages of local processing and interpretation offered by the Distributed Approach, without sacrificing the advantages of the Centralized Approach for strategic purposes. The key to doing so is the use in the field of interactive image processing techniques to selectively extract significant information from raw imagery for transmission over narrow band channels in greatly compressed form. Using such "edited" imagery, the central facility would assemble information from diverse sources into an overview for strategic and tactical

TABLE 2
CHARACTERISTICS OF REMSCAN DESIGN APPROACHES

	CENTRALIZED APPROACH	DISTRIBUTED APPROACH	HYBRID APPROACH
Communications	Sophisticated; state-of-the-art may be inadequate	Conventional, available now	Technology (MSAT) available 1989. Backed up by conventional methods
Data Processing and Interpretation	Totally centralized	Shipboard and other field sites	Interpretation in field. Processing split between field and central facility
Navigation	Dead reckoning (inertial). Shipboard access to external networks (e.g. LORAN-C, SATNAV)	Same	Same
Position-Fix (ice features relative to vessels)	Integrated navigation and imaging sensors	Same	Same
Hardware	"Dumb" terminals in field; very large main frame at central facility	Super-mini or main frame at each field location Mini computer at central facility	Mini computer at each field location. Mainframe at central facility
Strategic information including route optimization	Produced at central facility	Produced in field or not at all	Produced at central facility
Tactical	Produced at central facility	Produced in field	Produced in field. Forecasting carried out centrally
Close Tactical	In field	Same	Same

purposes, and would carry out forecasting and route optimizing as well as housekeeping functions.

6.2 Evaluation Procedures

There are several major criteria on the basis of which the three approaches described in Section 6.1 may be compared. Some of these (e.g. cost) are in principle quantifiable, whereas others (e.g. technical achievability) are subjective. The evaluation procedure adopted herein consists of assignment of a rating from 0 to 10 to each approach for each of the criteria, and summing to obtain a cumulative rating. For each criterion, a higher rating implies a more favorable assessment. This procedure was carried out from a strategic perspective, and independently from a tactical perspective. The results are given in Tables 3 and 4 respectively.

6.2.1 Evaluation Criteria

Definitions of the evaluation criteria used are given in this Sub-section, as follows:

- Image Processing Factors: This criterion related to an overall judgement concerning the ease with which a reasonable technical solution, satisfying the functional requirements for image processing and interpretation, can be implemented under the conditions imposed by each approach. Included are considerations of hardware/software availability, integration, of imagery with other data for interpretation, and ergonomic factors.

- Communications Factors: This criterion considers the availability of communications channels capable of providing sufficient bandwidth to accommodate the data rates envisioned in each of the three approaches. In addition, related technical factors such as, for example, the feasibility of mounting suitable antenna structures on board various vessels, are taken into account.

- Operational Factors: This criterion includes reliability, maintainability, space requirements, manpower requirements and aircraft support requirements.

- Expandability/Upgradability: Expandability refers to the ease with which the geographical coverage can be extended, the number of users can be increased, or additional user needs can be accommodated. Upgradability refers to the ability of the system to respond to technical advances such as improved equipment, hardware, or software and new information sources (e.g. Radarsat).

- Costs: Inasmuch as this study assumes that users will bear the capital costs of their sensors and that, wherever possible, existing services/facilities will be leased, capital costs are difficult to quantify at this stage and have been excluded from consideration. This criterion therefore reflects operating costs involved mainly in the provision of SAR aircraft support and communications channels, on the assumption that all functional requirements are met.

TABLE 3

STRATEGIC SITUATION RATINGS

APPROACH	IMAGE PROCESSING FACTORS	COMMUNI-CATION FACTORS	OPERATION FACTORS	EXPANDA-BILITY UPGRADA-BILITY	COST	CUMULATIVE RATINGS
CENTRALIZED	9	5	8	9	5	36
DISTRIBUTED	2	1	2	4	1	10
HYBRID	6	8	6	7	7	34

TABLE 4

TACTICAL SITUATION RATINGS

APPROACH	IMAGE PROCESSING FACTORS	COMMUNI-CATION FACTORS	OPERATION FACTORS	EXPANDA-BILITY UPGRADA-BILITY	COST	CUMULATIVE RATINGS
CENTRALIZED	5	1	6	9	1	22
DISTRIBUTED	7	8	8	4	5	32
HYBRID	8	5	7	7	7	34

6.3 Recommended Approach

The results of the evaluation procedure are shown in Table 5. The cumulative ratings for the strategic and tactical situations, obtained from Tables 3 and 4 respectively, clearly indicate that in each situation the Hybrid Approach is comparable to the best of the other two approaches. The ratings averaged over the strategic and tactical situations clearly favor the Hybrid Approach. This advantage is maintained when a weighted average, effectively assigning twice as much significance to tactical information as to strategic information, is used.

Broadly speaking, the Hybrid Approach is recommended because it avoids the major drawbacks implicit in the other two Approaches, namely, high technical risk and possible failure to meet all the requirements. With its use of in-field interpretation and processing, it is compatible with existing approaches such as that followed by the M.V. Arctic. It is also compatible with the centralized analysis facility concepts favoured by A.E.S., and by Canmar in its Beaufort Sea operations. The concept is functionally independent of the number of users.

The major technical characteristics of the Hybrid Approach are summarized below:

- Direct downlinking of imagery to suitably equipped vessels
- On-board image processing with some interpretation
- Narrow bandwidth long range communications; transmission of highly compressed imagery
- Central Facility does interpretation forecasting, route optimization, geo-referencing
- Highly processed tactical and strategic information backhauled to users

TABLE 5

COMPARISON OF THE THREE APPROACHES

APPROACH	STRATEGIC SITUATION RATINGS	TACTICAL SITUATION RATINGS	AVERAGE RATINGS	WEIGHTED* AVERAGE RATINGS
CENTRALIZED	36	22	29	26.7
DISTRIBUTED	10	32	21	24.7
HYBRID	34	34	34	34

* Tactical rating is accorded twice the weight of the strategic rating.

7.0 DESIGN REQUIREMENTS

In this part, design requirements for a baseline implementation of REMSCAN will be developed in terms of:

- The design approach recommended in Section 6.3
- The functional requirements described in Part 5.0
- A scenario of the activities requiring support to be described in Section 7.1 below

7.1 The Operational Scenario

It is assumed that, at the time of implementation of a baseline REMSCAN system, the major economic driving forces will be as follows:

- Limited year-round oil production from the Beaufort Sea region
- Production from the Hibernia field
- Ongoing resupply and grain trade activities in the eastern and high Arctic

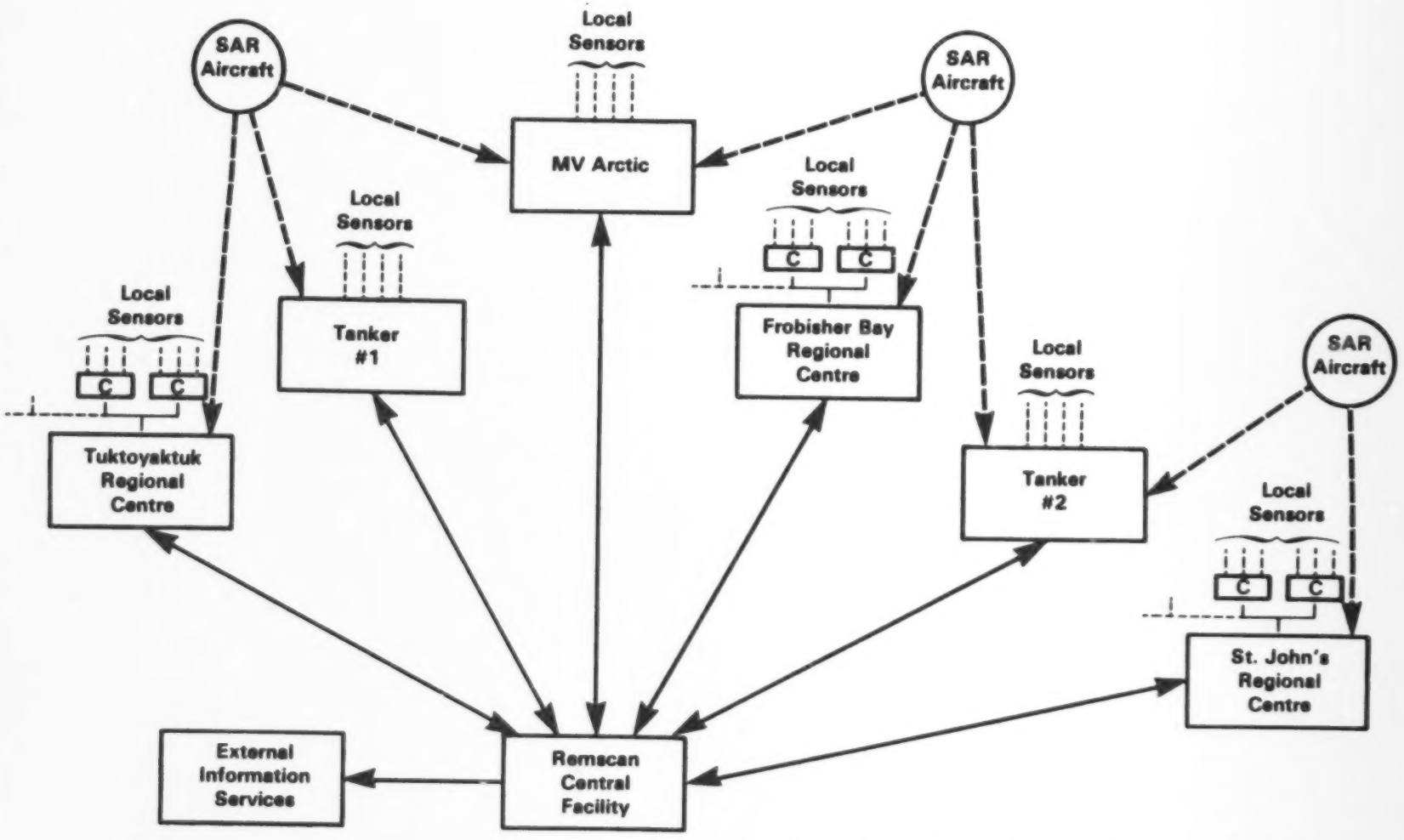
It is assumed that ice information will be required to support the following specific activities:

- 2 Class 10 oil tankers operating year round from the Beaufort Sea region (and possibly Cameron Island) to a southern Canadian terminal on the eastern seaboard.
- 1 upgraded ice class version of the M.V. Arctic operating with the high Arctic from early June to late December.
- A regional centre at Tuktoyaktuk to support year round offshore activity and vessel traffic connected with continuing oil exploration and production development in the Beaufort Sea. This centre would also service the needs of traffic entering the Beaufort through Bering Strait.
- A regional centre at St. John's to support Hibernia/ Newfoundland tanker traffic, activities connected with continuing exploration and production development of Hibernia and exploratory drilling in the Labrador Sea.
- A regional centre at Frobisher Bay to coordinate icebreaker support, and general vessel traffic management functions for the resupply and grain transport traffic.

7.2 REMSCAN System Configuration

The proposed system configuration closely parallels the operational scenario described in Subsection 7.1. It is illustrated schematically in Figure 9.

The basic elements comprise a central facility (REMSCAN, Central) located near major A.E.S. facilities in Ottawa or Toronto, six primary field stations located at each of the three major vessels and at the three regional centres. A number of secondary vessels or sites are "clients" of each of the regional centres (or, under some circumstances, major vessels).



Note: 'C' Designates a Secondary Vessel or Fixed Site

CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN SYSTEM CONFIGURATION
		FIGURE No. 9

REMSCAN Central houses major information processing and image interpretation facilities and is the location of the main REMSCAN interface with external services provided by A.E.S., radarsat, etc.

All primary field stations acquire and preprocess raw data, and receive processed information directly from REMSCAN Central. The major vessels are themselves end users of REMSCAN information and sources of raw data. The regional centres on the other hand each re-distribute information to, and receive raw data from, their clients.

SAR imagery is downlinked directly to the primary field stations for preprocessing and onward transmission to REMSCAN Central. The major vessels make additional use of raw SAR imagery for close tactical purpose, a function which lies outside the scope of REMSCAN.

Note that the SAR aircraft are external to the REMSCAN system, and are contracted by the end users individually or by joint agreements among themselves. The number of aircraft shown in Figure 9 is purely arbitrary. The actual number of SAR aircraft in service during any particular period would be dictated by operational and environmental considerations.

REMSCAN would of course acquire and utilize the SAR imagery and would make recommendations to the users regarding coverage needs. In those cases where an information gap became apparent, the REMSCAN infrastructure would provide for additional SAR services.

Table 6 indicates the way in which major REMSCAN systems functions are allocated to the various elements.

7.3 Input Data Requirements

REMSCAN output information will depend upon:

- The kind and quality of input data
- The frequency at which it is updated

Based on present experience, the REMSCAN workhorse will be imaging radar, probably synthetic aperture radar (SAR). SAR imagery contains information on:

- Ice distributions
- Open water regions
- Ice type (with expert interpretation and auxiliary information).

No accepted criteria exist for the frequency at which imagery should be updated. The frequency necessary to maintain the integrity of the output information is a critical system operational parameter affected by:

- Ice motion
- Ice conditions
- Ice forecast reliability
- Weather conditions (visibility)
- Vessel design/operating parameters

TABLE 6

TABLE 6: ALLOCATION OF REMSCAN FUNCTIONS

CENTRAL FACILITY	MAJOR VESSELS	REGIONAL CENTRES	SECONDARY VESSELS/ SITES "CLIENTS"
- Receive Pre-Processed imagery and other data from major field stations	- Acquire raw data or local conditions	- Acquire raw data (message/text) from secondary vessels, sites	- Acquire raw data on local conditions
- Interface with external agencies	- Validate, time stamp	- Validate, time stamp	- Transmit to REMSCAN Regional Centre
- Image Processing, Interpretation	- Receive SAR imagery	- Receive SAR imagery	- Request/receive REMSCAN information
- Validation of data	- Preprocess/pre-interpret imagery	- Pre-process/pre-interpret imagery	- Display REMSCAN information
- Forecasting	- Compress imagery for transmission to central	- Compress imagery for transmission to central	
- Route Optimization	- Transmit compressed imagery	- Transmit compressed imagery, raw data to central	
- Image data base management	- Transmit formatted data (met, nav, performance, etc)	- Respond to message requests from central for more data	
- Maintain overall image data catalog	- Respond to message requests from central for more image data	- Receive/store regional data base from central facility	
- Monitor vessel traffic	- Receive/store information packages from central facility	- Retain descriptions of information packages required by each client	
- Retain descriptions of information package required by each major field station	- Display REMSCAN information	- Assemble/transmit information packages to clients	
- Monitor image data base for deficientcies; initiate corrective data requests	- Maintain local archive	- Manage communication links to clients	
- Manage commonication links to major field sites		- Maintain local archive	
- Maintain archived storage			
- Assemble/transmit information packages to users			

Rather than by formula, it is possible that SAR flight dispatch might be based upon observed (or expected) discrepancies between actual ice conditions and the most recent imagery. This function could in principle be automated. Expected SAR flight frequencies are indicated in Figure 10 (a), (b), (c), (d), (e).

Local data sources would include:

- Marine radar
- Visual observation of ice
- Drifter buoys
- Meteorological sensors
- Ocean current meters
- Navigation/position-fix equipment

These would be used for close-tactical purposes, and as adjuncts to radar imagery (surface truthing, etc). This information is of course available quasi-continuously.

The image preprocessing and interpretation processes at the primary field stations and at REMSCAN Central would be the main points at which these varied data are incorporated into the information production process. The principal roles of these data are:

- To provide supporting information for the interpretation function
- To provide primary inputs to the forecasting process (e.g., ice velocity observations)

In addition to being utilized at the primary field stations, these data would be time stamped, catalogued, stored, and as required, forwarded to REMSCAN Central.

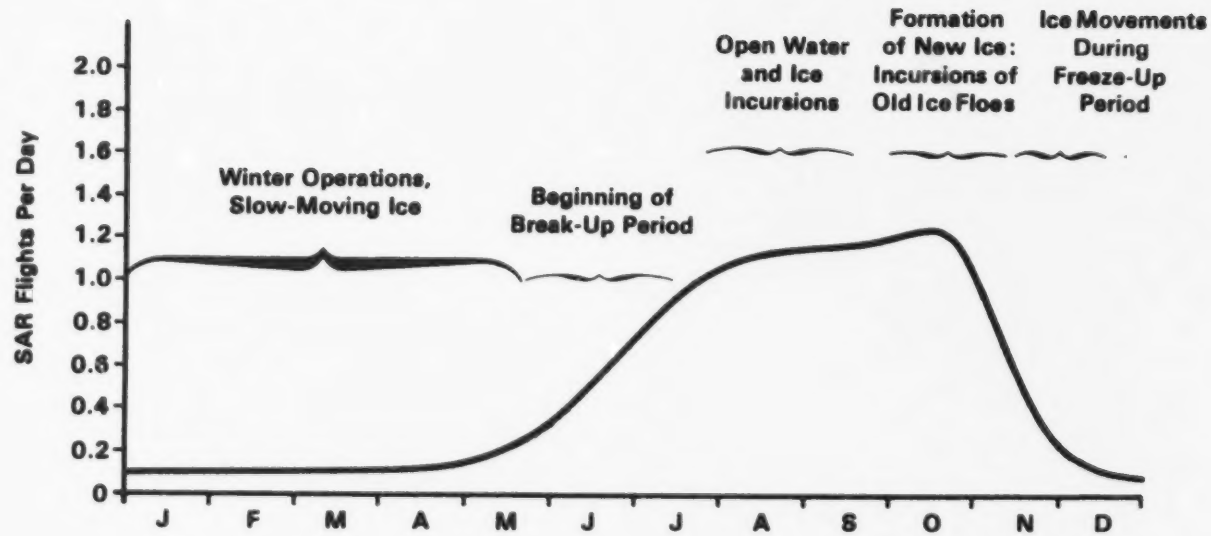
7.4 Output Information Requirements

The basic data management approach to be followed by REMSCAN is the integration of all available data into a comprehensive map data base covering the entire region of interest, at a level of detail sufficient to accomodate tactical as well as strategic needs.

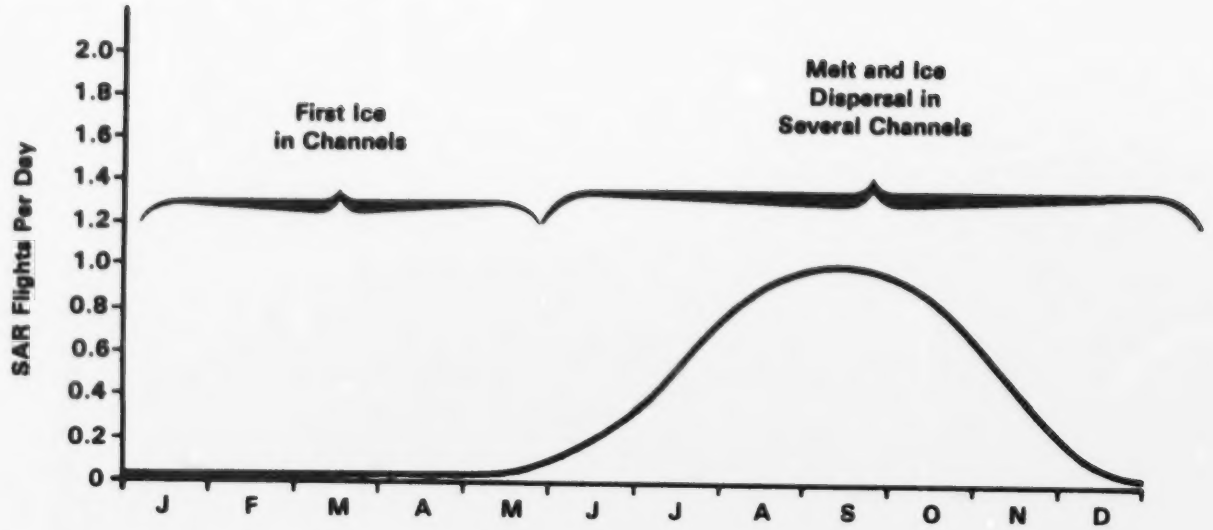
The process of tailoring the output to individual user requirements would then comprise:

- Selection of a subset of information covering the region and time span of interest
- Formatting of the information in a manner technically compatible with the particular user's equipment

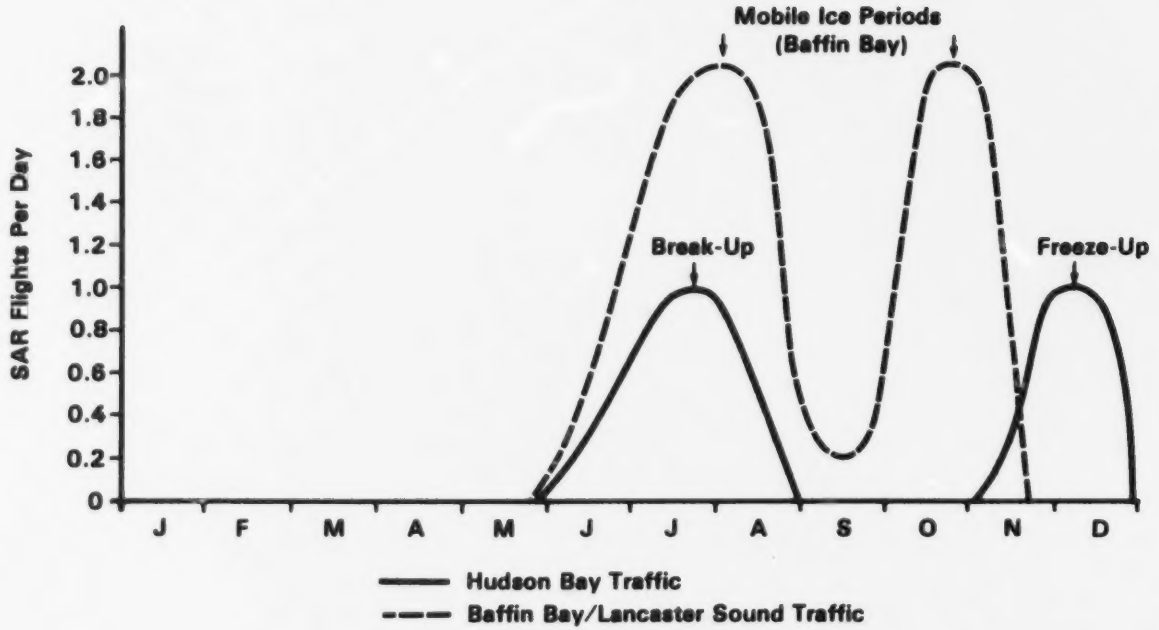
In the following Subsections, the output data formats are described without reference to the detailed specifications of any particular equipment. The latter would be selected at the option of the user, and it would be the function of the REMSCAN interface to ensure full compatibility.



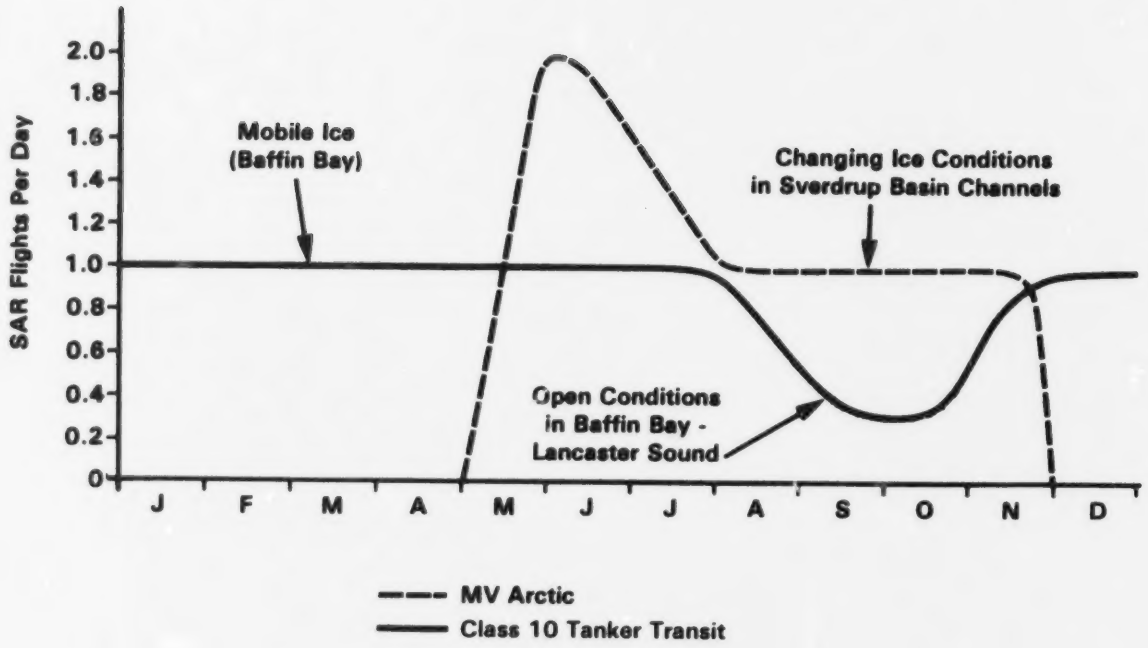
CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: TUKTOYAKTUK: LOCAL TRAFFIC SAR SUPPORT FIGURE No. 10(A)



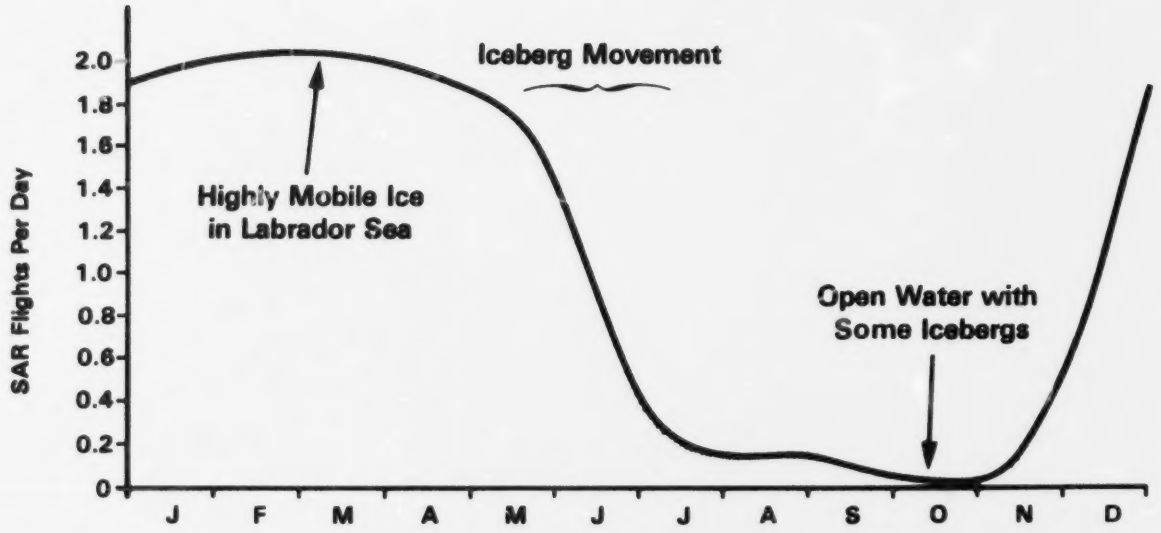
CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: CLASS 10 TANKER TRANSIT SAR SUPPORT (WESTERN ARCTIC)
		FIGURE No. 10(B)



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: FROBISHER BAY SAR SUPPORT
		FIGURE No. 10(C)



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: EASTERN ARCTIC SAR SUPPORT
		FIGURE No. 10(D)



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: ST. JOHN'S SAR SUPPORT: ALL TRAFFIC, TANKERS AND ICE-BREAKER SUPPLY ROUTES
		FIGURE No. 10(E)

7.4.1 Colour-Coded Map Format

The requirement for a resolution level of 1% of full scale, expressed in Section 4.2, translates to a video display resolution of 100 lines. The use of texture coding, however, involves overlaying parts of the map with fine patterns, thus increasing the resolution requirement. Experience suggests that 500 lines horizontal and vertical display resolution would be adequate for this purpose.

Sufficient display flexibility to handle the vast majority of information presentation requirements would be provided by the use of 8 colours and 4 textures. This would permit the capability in principle to unambiguously distinguish 30 ice forms plus land and open water. The requirements of this format are technically compatible with currently available CRT and hard copy equipment.

7.4.2 Monochrome Map Format

The basic map resolution requirement is as for the colour format described in Subsection 7.4.1, namely, 1% of full scale or 100 lines. Although some use of texture coding is possible, experience suggests that the map display be used to describe the boundaries of ice domains, etc., with condensed annotation used to describe ice types. The display must therefore have sufficient resolution to accomodate ice description such as WMO "Egg Codes", symbolic references to accompanying tabular material, or both.

As in the case of the colour format, an overall level of video resolution of 500 lines vertical and horizontal, or equivalently, 0.2% of full scale, is deemed to be adequate. Again, the specification of display/presentation equipment is at the users option, with responsibility for compatibility assigned to the REMSCAN interface. It should be noted that the proposed level of resolution is easily achievable with available facsimile equipment. This format is also of course compatible with colour map equipment.

7.4.3 Message Format

Information conveyed in this format consists of alphanumeric description of synoptic conditions or response to specific user queries. It is foreseen that the preparation of messages would require the services of a REMSCAN operator.

Messages could be transmitted and presented using any medium compatible with alphanumeric text. This would include those media and equipment which are normally used for colour or monochrome map presentation, as well as voice or printer channels.

7.5 Regulatory Requirements

Existing Canadian regulations, codes and standards for marine transport operations pertain essentially to vessel safety and environmental protection. In terms of REMSCAN-type activities, such regulations define minimum requirements for marine communication and

navigation systems. There are apparently no regulations dealing specifically with remote sensing systems except within the context of communications and navigation.

Domestic Canadian regulations and standards are usually based upon international agreements so as to form a subset of the more comprehensive but less specific international document. Typical of such agreements are the World Administrative Radio Congress (WARC) sponsored by the International Telecommunications Union (ITU) and the International Convention for the Safety of Life at Sea (SOLAS), sponsored by the International Maritime Organization (IMO).

7.5.1 Navigation

Regulations for marine navigation are stated in the following Federal Acts (2) (3)::

- Canada Shipping Act
  - Navigating Appliances Regulations
  - Emergency Position Indicating Buoy Regulations
  - Charts and Publications Regulations
  - Ship's Deck Watch Regulations

- Arctic Waters Pollution Prevention Act
  - Arctic Shipping Pollution Prevention Regulations

Canadian waters north of the 60th parallel are divided into shipping safety control zones as shown in Figure 1. Marine traffic traversing the Northwest Passage must meet regulations specific to zones 2, 6, 9, 10, 11, 12 and 13.

Requirements for shipboard navigation equipment are dependent upon a vessel's gross tonnage, construction class and the safety control zones in which it will operate. The most stringent requirements apply to vessels of 1,600 tons, gross tonnage, or more. These requirements are summarized below:

- Two magnetic compasses.
- Two gyro compasses.
- Two marine radar installations.
- Two echo sounding devices.
- Navigating instruments and publications to determine compass error and positions by astronomical means.
- One facsimile terminal capable of receiving information from Halifax, Edmonton and ice reconnaissance aircraft on the frequencies listed in the Transport Canada publication, "Radio Aids to Marine Navigation" (4).
- Radio direction finding apparatus.
- Spare parts and operating and maintenance manuals.
- All applicable navigating charts and publications.

7.5.2 Communications

The following acts contain regulations applicable to marine communications (2) (3):

- Radio Act

- Canada Shipping Act
  - Ship Station Radio Regulations
  - Ship Station Technical Regulations
  - Navigating Appliances Regulations
  - Emergency Position Indicating Buoy Regulations
  - Arctic Waters Pollution Prevention Act
  - Arctic Shipping Pollution Prevention Regulations

The Radio Act broadly defines the use of the radio spectrum in Canada in accordance with international frequency allocations agreed to at the latest WARC meeting. Further, the act states the qualifications for operators using land, sea and air communications equipment. The frequency bands are allocated to a wide variety of services including navigation, mobile operations, and meteorological aids. The microwave band from 2.31 to 2.39 GHz has been assigned to aeronautical telemetry applications such as required for downlinking SAR/SLAR imagery from aircraft.

Minimum equipment requirements are stated in the Ship Station Radio Regulations and Ship Station Technical Regulations with additional requirements for northern voyages given in the Arctic Pollution Prevention Regulations. The necessary type and quantity of shipboard communications is dependent upon:

- Ship gross tonnage.
- Whether a ship is carrying passengers, pollutants or other cargo.
- Whether a ship will operate in Canadian waters having radio coverage from Coast Guard radio stations in the MF, HF or VHF bands.
- Whether a voyage will take a Canadian ship into international waters not having HF coverage from Canadian shore stations.
- Whether a ship will operate in shipping safety control zones north of the 65the parallel.

A tanker operating in the Northwest Passage would typically require the following communications equipment:

- One bridge to bridge VHF radiotelephone installation capable of operation on marine channels 6, 14, and 16.
- One MF radiotelephone installation equipped for operation on 2182 KHz, 2638 KHz and at least two other frequencies in the 1605 to 2850 KHz band that serve the area in which the ship is located.
- One combined MF/HF radiotelephone installation that is able to communicate in the 4 to 16 MHz band with coastal radio stations serving the area in which the ship is located. At least one channel in each of the 4, 6 and 8 MHz bands are required.
- One VHF receiver capable of continuous monitoring of marine channel 16 or a marine receiver capable of receiving navigational warnings in the area in which it will be operating.
- An HF receiver capable of continuously monitoring 4409.4 KHz.
- One facsimile terminal capable of receiving fixed images from ice reconnaissance aircraft and shore radio stations.

- One MF radiotelegraph installation capable of operation between 405 and 535 KHz including 410 KHz for direction finding and 500 KHz for emergency distress calling.
- MF radiotelegraph alarm signal keying device.
- Radiotelegraph audible auto receiving alarm.
- MF radiotelephone two-tone alarm signal transmitting device.
- Lifeboat radiotelegraph transceiver.
- Emergency position indicating buoy.
- A communication system internal to the ship.

In accordance with regulations established at the 1974 SOLAS convention, the Canadian Government can authorize the use of satellite communication facilities for Canadian cargo ships when making occasional international voyages. A radio officer and radiotelegraph installation will not be required on these ships, although MF, HF and VHF radiotelephone facilities would continue to be necessary. The satellite installation must include a telephone and telex facility.

7.5.3 Other Regulations

- Arctic Waters Pollution Prevention Regulations
- LPG Gas Regulations
- Oil Pollution Prevention Regulations
- International Radio Regulations of the ITU

7.5.4 NORDREG

NORDREG Canada is the name of the vessel traffic management system for Canadian Arctic Waters. The NORDREG zone covers all waters north of 60^{0} North Latitude including Ungava Bay, Hudson Bay and James Bay but excluding MacKenzie Bay and Kugmallit Bay.

The system serves to monitor and coordinate transportation in Arctic waters by providing a formal interface between the Coast Guard and Arctic Shipping. Participation in the system is currently voluntary, although a Pollution Prevention Officer may use NORDREG facilities to issue instructions under the Arctic Waters Pollution Prevention Act. The system is applicable to vessels of 300 tons, gross tonnage, or more, ships carrying a pollutant type cargo, and certain ships engaged in towing operations.

Communications between the NORDREG Operations Centre in Frobisher Bay and ships is provided at no cost by the Coast Guard through their coastal radio network. An automated data base aids in monitoring ship movements. Participating vessels are required to report to NORDREG daily and also when crossing the zone boundary. The report consists of the ship's name and position, weather conditions, visibility, and ice conditions. Requests for icebreaker assistance are made through NORDREG.

7.6 Remote Sensing Subsystem (RSS) Requirements

7.6.1 Hybrid Remote Sensing Subsystem

The RSS is the primary REMSCAN subsystem as it embodies all the principles of the integrated ice surveillance concept; all other subsystems mainly support the RSS by providing collaborative information for enhancing the value of remotely sensed data. Intera Technologies Ltd. was tasked to examine the primary function of the RSS, Image Processing, with a view towards determining which REMSCAN approach was the most usable for achieving the image processing objectives of REMSCAN. The complete report is attached as Appendix B, however the conclusions are summarized below.

With respect to the Remote Sensing Subsystem:

(i) A Central Facility is generally superior to a Stand-Alone capability for achievement of strategic functional requirements;
(ii) A Stand-Alone capability is generally superior to a Central facility for tactical and close-tactical requirements; and
(iii) Neither approach can, by itself, totally support all functional requirements except at what would be a prohibitive cost.

The above conclusions indicate that a Hybrid system containing elements of stand-alone and central facility will produce the optimum system.

It is furthermore expected that the Hybrid system will vary somewhat with user preference. That is, the amount of on-board capability will likely be a variable according to user requirement. The central facility output products are more likely to be constant except for those products which are produced in response to specific queries.

As stated earlier, the REMSCAN evaluation assumes that there will be no revolutionary advances in technology. Solutions to REMSCAN operating scenarios (1987 and beyond) will be found using today's technology, some of which at best is still in the preliminary design stage (RADARSAT, MIDAS, etc).

The extent of hybridization will be determined by the following:

- Unique customer requirements (stringent operating efficiencies versus minimum regulatory requirements)
- Type of vessel or platform
- Amount of vessel traffic
- Availability of remote sensing resource (SAR, SLAR, aircraft)
- Geographic parameters (time of year, meteorological, ice, sea state conditions)
- Status of REMSCAN development (consistent with the concept of an evolutionary and upwards compatible development)
- Status of remote sensing technology (RADARSAT, fluorosensor, sonar, advanced marine radar)
- Status of image processing and display technology

Remote Sensing Subsystem requirements consistent with the hybrid approach, were developed by scientists from Dome and Intera Technologies Ltd. This section of the report comprises the joint philosophy which evolved from several discussions and draft reports.

7.6.2 Tasks of the Remote Sensing Subsystem

Section 5.2.2.1 outlined in conceptional terms the functions of the RSS. More specifically the RSS must perform the following tasks:

- Receive a wide range of input data (i.e. predominantly imagery but text may also be used to report ice features).
- Produce output products compatible with a wide range of users and vessel technologies.
- Influence direct exchanges of remote sensing information among users (i.e. if information/imagery can be exchanged without additional processing).
- Synthesize remotely sensed data to enhance, through synergistic effects, tactical and strategic ice information.
- Detect, identify and track potentionally hazardous ice consistent with tactical and strategic requirements of user vessels.
- Display remotely sensed data to aid analysis and present information in a straight forward manner.
- Communicate with other REMSCAN subsystems, in particular the navigation and forecasting components, to ensure timely production of output products.

These tasks can be broadly categorized into three major groups: acquisition and distribution of data, image processing, and analysis. Image processing is covered in detail in the Intera Report (Appendix B). The remainder of this section will concentrate on the other two.

7.6.3 Subsystem Description

The constraints placed on REMSCAN by the lack of easily accessed wide band communications have dominated all design assumptions. It is clear that insufficient raw data will be available to ships' operators to make decisions of a strategic nature. Equally, it is obvious that tactical information available on the ship (SAR/SLAR, marine, radar, sonar, etc.) cannot be relayed to the central facility, without considerable compression. If we extrapolate from current operations, we can foresee no substantial vessels attempting extended or full season operation, without an ice analyst aboard. The overall costs of using either an experienced or junior person is roughly equivalent and the potential savings from quality information is so high in terms of faster, lower fuel cost transits that we foresee an experienced ice analyst on every vessel.

It should therefore be practical for the ice observer to reduce all the tactical information available to him, to high quality strategic data in no-image format for entry into REMSCAN. Further, for the information to be used by REMSCAN analysts, it must be produced in such a way that the users have confidence in the data reduction. Therefore the shipborne capability must be reliable. This fact emphasizes the

acceptance in the REMSCAN concept of the requirement for vessel autonomy and self-sufficiency for close tactical and most tactical operations. REMSCAN will also enhance the strategic decision making capability of vessels as well as providing tactical information not otherwise available to particular vessels due to varying inadequacies in dedicated remote sensing resources.

REMSCAN will acquired remotely sensed data in one of two ways. The first means would be directly from its own resources or subscriptions to remote sensing services; examples of these would be as follows:

- Commercial SAR/SLAR aircraft
- AES SLAR
- NOAA/TIROS (visual/IR)
- LANDSAT
- RADARSAT
- AES meteorological stations

The second means of acquiring data would be indirectly; that is, in a compressed or reduced form from vessels operating in a REMSCAN serviced region. Examples of indirect data sources are:

- SAR/SLAR flights supporting vessels
- Ships heading and speed log
- Visual
- Marine radar
- Weather, seastate monitoring sensors (normally associated with static platforms)
- Periodic reports from vessels (text, radio, facsimile)

In the first, direct method, data may be acquired directly in high bandwidth form but must be synthesized and compressed by the RSS before it can be transmitted to vessels. Also, depending on the type of information and timeliness requirements, other means are possible for directly transmitting data to REMSCAN; for example, hand delivering SAR imagery (high density data tapes) or by narrow band data links from the aircraft's land base at the end of a mission. The reverse is true for the second, indirect, method. Data must be compressed and formatted at source to allow relevant information to be extracted for transmitting to REMSCAN via the narrowband REMSCAN communications facilities. The particular means by which information is exchanged could range from a simple telex to sophisticated imagery compression techniques.

There is a third category of data exchange which may or may not take place as a result of REMSCAN direction; that is, transmittal of data directly between ships as they encounter each other. Generally speaking, encounters of transiting vessels would be infrequent, given the expected volume of traffic in the Northwest Passage. On the other hand, direct exchange could be the norm for servicing clusters of offshore static platforms or convoys. REMSCAN's role in such data exchanges would be to ensure that vessels are aware of the presence of other vessels and to provide advice on the useability and timeliness of that data exchanged. The extent of data exchange, whether by wide band dumping of imagery between suitably equipped vessels or by means of

verbal reports over the radio, would depend on the cooperation of companies (who would likely be competitors) and the law of the sea. REMSCAN would monitor such exchanges for completeness and would subsequently provide any additional information on hand. This monitoring function would be performed by the SCIP which would prompt the RSS to provide any information that is additionally required. This third category, will not be emphasized as it will likely be infrequent and data transfer of any magnitude will be line-of-site limited (i.e. approximately 35 miles or 2 hours for ships travelling at six nautical miles per hour).

7.6.4 The Shipboard Tactical Environment

It is worthwhile, at this point, to consider the tactical environment which is expected on a sophisticated tanker, from a remote sensing point of view. An example will serve as a baseline from which most other hybrid RSS operations can be extrapolated.

Strategic information obtained from REMSCAN (or other agencies if REMSCAN is not fully developed) will influence the selection of the route which the ship will follow. Having chosen the general course, it will be imaged, and the image downlinked to the ship, by an airborne radar. Experience with the M.V. Arctic has shown that it is not only hazardous ice conditions that will be imaged, highly variable ice conditions which contain large amounts of open water will also be imaged. By route selection, substantial savings are available both in reduced fuel costs and decreased transit times. The useful lifetime of these data will be inversely proportional to the mobility of the ice, at least for the purposes of tactical, floe by floe or lead navigation.

The ship will use airborne SAR data, in conjunction with its own limited range radar's display, to make its way through the ice. The display and analysis of the airborne radar imagery, for the ships own purposes will involve classification of ice types and hazard detection. This will, at least for the next few years, be done using interactive, display based algorithms. It is during this process that data compression for transmission to REMSCAN would likely take place. As this will be an extra task, it must be clearly defined, and be streamlined. Otherwise when the ice conditions are most critical, and the ice observer is busiest, the data abstraction will be left out to the detriment of all other potential users.

Note that in this example the shipboard interactive workstation and dedicated airborne radar are not REMSCAN resources but are used for close tactical and tactical vessel operations. They do, of course, embody the principles of REMSCAN at the shipboard level and may eventually share integrated components such as displays and data links.

The purpose of the analysis aboard ship would be to optimize the ship's path through the ice. Fine resolution airborne imagery can be used as a navigation chart, to guide the ship around hazards. Also, a composite display can be used to show both an overview and a blowup of the ice in the area. The overview would show an area of many 10's to 100's of kilometres on a portion of the display screen. The blowup

would show the ice some 10 km or less in advance of the ship, on a larger portion of the screen. The prime image parameters used by the ice observer are the relative brightness and texture of the ice, and the shapes of the brightness patterns. Thus, the interactive display would be the main analysis tool with zoom, roam and grey scale enhancements as the main actions.

Classification by automatic means is not expected to be used in the foreseeable future.

7.6.4.1 Shipboard Interactive Workstation

As stated earlier the shipboard interaction workstation, is not technically part of REMSCAN because it is necessary for vessel autonomy. Such terminals may be low technology in the form of a conventional chart with hand drawn ice information, or high technology such as the Intera Technologies Ltd. development MIDAS. These high technology terminals embody the principles of REMSCAN at a shipboard level and much larger, enhance, versions may be components of a central REMSCAN facility. Developments such as MIDAS are at the conceptual stage only; however, some discussion is necessary in order to put the role of the shipboard interactive terminal in perspective with the overall REMSCAN concept.

MIDAS is intended to be primarily a tactical and close tactical tool. SAR data would be acquired and stored in a geo-referenced data file. Tactical SAR data could be made available to the interactive work station at several different resolutions, for display or a digital video screen. Resolution defines the extent (or scale) of imagery as the image display has a fixed size. The analyst would use SAR data to recommend to the ship's master a course which minimizes the cost of traversing ice infested waters. Imagery, as displayed, must be detailed enough to provide an accurate idea of what ice conditions will be encountered, and cover sufficient extent to allow course optimization. Without a wide ratio zoom, or multiple scale display, this appears to be impractical. MIDAS will have a windowed display with both an overview and a blowup present on the screen.

The image presented must not only be interpretable by the ship's ice observer, but by the ship's master. Otherwise it will lead to uncertainty and mistrust. Therefore, the quality of the visual display will be of the utmost importance. Such things as colour enhancements based on sophisticated lookup tables will be of advantage to the ice analyst but a high quality black and white display will be of primary importance.

Because the ship and the ice both move, the earth's co-ordinate system will be used as the reference for all data. The ship will know its speed and location relative to the ice. Similarly at the time of data collection, the SAR imagery will be referenced by the aircraft navigation system. The ships marine radar will be used to tie together, as the ice shifts, the location of the ship and the ice imagery. This will be one of the more important functions of an ice observer. This complex pattern matching operation is not a task for which a computer is

well suited, so the image analyst will be charged with tracking the ships position on the SAR imagery. The REMSCAN Navigation Subsystem will be used to geo-reference in absolute terms, the positions of ice and vessels in the strategic sense to allow exchanges of position information.

MIDAS will accept data from SAR, marine radar and the ship's navigation system, as well as other ice sensors such as sonar, feeding into an analytical work station. There, using multiple image screens, the SAR and marine radar are analyzed and combined with other data to provide tactical and close tactical support. Data set abstraction, for transmission to clients can be performed by narrowband television. While this was originally included to facilitate the support of vessels from a fixed base, such as that in the Beaufort Sea, it would be a practical way of relaying quality data to client ships. An example of this would be an ice breaker supporting a number of smaller freighters delivering supplies to an area such as Labrador or Baffin Island.

The REMSCAN system would specify and/or provide the format and hardware for the ship to communicate with REMSCAN Central. As shown in Figure 4, REMSCAN Central would act as a focal point and clearing house for all data which contributed to the strategic and tactical overview. As well, the strategic route navigation would be done there, along with the orchestrating of aircraft SAR support. When convenient, ships passing each other could exchange data at downlink data rates, when within line of sight.

The two concepts, REMSCAN and MIDAS, can thus be seen to be compatible even when a ship is equipped with its own capability for acquiring SAR data and integrating it with other shipboard sensors. The role of REMSCAN becomes more important as the technical sophistication and capability of vessels decreases.

7.6.5 Shipboard Data Abstraction for REMSCAN

While the prime analysis aboard ship will be done mainly for tactical navigation support, the data will be abstracted and made available to REMSCAN. The nature of the data abstracted, and the actual data sent are the subject of this section. As stated offtimes before, REMSCAN must be upwardly compatible with future developments in data analysis and communications technology. However, it must also be upwardly compatible with what is currently done and the abstraction process must have a reasonable chance of being accomplished, under all conditions, not just when the ice observer has sufficient time to dedicate to this task.

The first and simplest method of data abstraction is to simply reduce the resolution of the data. For example, STAR-1 data as available on the M.V. Arctic, have a bandwidth of 256 k bits/sec. This is some two orders of magnitude greater than the links to be available from the ship to REMSCAN. On the ship, the size of the pixels will be reduced to create the overview image to some 250 m x 250 m. With this size of pixel, and only 3 bits of intensity information, data retransmission times would be between 1/5 and 1/10 of the the actual data

collection times. The experiments done at INTERA suggest such images would in fact be useful, when combined with other data sources. For example, a single flight line of data used by the M.V. Arctic over a period of one full day accompanies an image of 50 x 200 km in size. Reducing this to 250 m (3 bits) resolution, the image, which took better then 1/2 hour to collect could be sent over a phone line in some 5 minutes.

This could be used in several ways. For example, when used with the ice charts, and other strategic data, it would allow finer analysis. Further combining with the actual ships track, and detailed observations from the ship would greatly increase its utility. Detailed data as listed below could be sent.

- Reduced Resolution SAR Image
- Ships speed and direction in the ice
- Ice drift (from MIDAS)
- Ice thickness observations
- Detailed meterological observations

In addition to these low rate, low effort data, there are other types of data that are available from the ship. For example, if the 250 m data do not satisfactory answer a REMSCAN question, a request for a blowup could be made. The technique of differential transmission could be used (for example) to minimize the amount of data transmitted. This could be requested from the computer on the ship and have little or no impact on the ice observer's work load.

The data available on the ship could be further analyzed, by the ice observer, to produce a whole series of products, on a very fine scale, for REMSCAN. These are as follows:

- Ice Type Classification Chart
- Floe size distribution
- Iceberg count on a grid
- Detailed ice obstacle report

These analyses would require the ice observer to have both time available, and an image analysis system. Since it is unlikely the ship will carry two systems, this will perforce be a background analysis conducted on the main system. If the work demanded, this could be time shared, on a separate display system. However, it is current opinion that these more complex and esoteric analyses will be slow in preparation because of higher priority activities supporting tactical operations. Thus, a centralized REMSCAN facility would be more capability for providing such analyses.

This set of data abstractions is based on the currently available, and practical operational and technological scenarios both aboard ship and on land. The tasks proposed for the ship based system can be consistent with the range of tasks performed by busy, ship centred ice observers. It is also upward compatible as communications technology progresses.

7.6.6 Remote Sensing Subsystem Facilities

7.6.6.1 Shipboard RSS Facilities

The type and complexity of RSS facilities aboard ship will depend to a large extent on customer preference, but specifically on:

- Type and complexity of shipboard interaction work station (i.e. MIDAS)
- Types of information products required
- Type of data input from vessel
- Complexity of other REMSCAN components on board, notably communications and information processing.

Vessels equipped with MIDAS may not require a special, dedicated RSS terminal as it is expected that MIDAS will contain, as an option, a two-way REMSCAN interface. On the other hand, some vessels (static platforms for example) may rely totally on REMSCAN provided information and would be equipped solely with an RSS terminal similar to a MIDAS but totally reliant on external data acquisition and analysis. For low technology vessels, the radio, facsimile, or telex may serve as input/output devices for REMSCAN subscribers.

7.6.6.2 REMSCAN Central RSS Facilities

Generally speaking, the REMSCAN Central referred to in the hybrid approach is a central facility, or headquarters, with several regional centres supporting areas of greater intensity, such as, for example, the Beaufort Sea or East Coast. REMSCAN Central (and the Regional Centres) will likely be based on present in-service facilities shared by government and industry (Beaufort Weather and Ice office, for example) or on government alone (AES and CCG regional offices). Furthermore, the Regional Centres may be operationally identical to sophisticated tankers or icebreakers which serve various client vessels (see Section 7.2). To avoid duplication of capability, however, REMSCAN Central and these Regional Centres should be thought of as one, as long as they are interconnected with suitable communications. In this way, it would be necessary to duplicate (for example) data storage facilities because principles of distributed data base and processing would influence the ultimate design.

The remote sensing capability of all present and future government and industrial facilities need only be linked together so that data from all sources could be combined, displayed and analyzed by the RSS. The central RSS facility would have access to data from sources as follows:

- Synthesized data from vessels
- REMSCAN owned data from regional SAR flights, meteorological stations, etc.
- REMSCAN subscribed data from NOAA, LANDSAT, RADARSAT, etc.
- Government owned data from AES SLAR, weather stations, forecasting services, Ice Central, etc.

The RSS facility location at REMSCAN Central (or the Regional Centres) would contain the following components:

- Image processing system (larger version of MIDAS)
- Mainframe computer
- Ground stations for NOAA, LANDSAT, RADARSAT, etc.
- Data entry operators
- Scientists for interactive analysis of ice data
- Direct connection SCIP and Navigation Subsystem (see REMSCAN Block Diagram Figure 12)

7.6.7 REMSCAN Central Output Products

As stated previously, the output product will depend on customer preference or his individual ability to receive a particular data type. For high technology vessels, those that are totally autonomous for the purposes of tactical support, the single most important task of REMSCAN Central would be high quality strategic support. Currently aboard the M.V. Arctic, ice charts are combined with V/IR satellite imagery received aboard the ship and ice motion forecasts estimated from weather charts. The result is an attempt to optimize the path taken by the ship. This task is presently being carried out with a limited data set and minimal forecast support. Assuming that high quality could be maintained, and therefore client confidence, this function is best performed by a facility like REMSCAN Central.

Receiving, compiling and integrating data from client ships into the strategic data base is another major function of REMSCAN Central. Specifically, the abstracted SAR imagery with ships paths will need to be analyzed, and combined with other data sources. Requests for finer resolution data over areas in question could also be handled. Combining the detailed meteorlogical data from vessels into existing weather charts will result in improved weather data for ice modelling. Running the ice models, with detailed ice thickness and ice motion data from the ships would be another REMSCAN task but not that of the RSS. The analysis of the modelling data, for ship strategic planning would be done by the SCIP (see Section 7.9).

Low technology vessels will require this same strategic information as well as timely tactical information in products which are compatible with their means to receive it. Furthermore, there will be client vessels with various requirements ranging between the two extremes.

A non-exhaustive list of these output products and information handling requirements from REMSCAN Central is as follows:

- Strategic information to vessels
- Responses to enquiries of a strategic nature
- Requests for tactical/regional over flight
- Ice maps and charts (current conditions, forecasts)
- Warnings to mariners (radio, facsimile, television)
- Regional ice situation reports
- Vessel specific ice reports

- Status reports of remote sensing platforms, vessel traffic, weather stations
- Data source reports (current and scheduled)

7.6.8 Summary of RSS Requirements

- Must receive imagery, georeferencing data and site specific reports from all sources.

- Must perform image analysis, mosaicing, and enhancement to assist operator in classifying ice types and identifying obstacles.

- Must be interactive and operate in near real-time.

- Must produce maps and charts of the following types: color coded, black and white (egg-code), grey scale.

- Must produce interpretive reports (text) for transmission by radio, telex, etc.

- Must perform interactive/semi-automatic tracking of selected ice targets.

- Architecture and data formats must be organized on regional basis to facilitate mosaicing, georeferencing and forecasting functions i.e. regions will be defined by permanent grids against which all data will be referenced. Size of grid cell can vary but should be consistent with resolution requirements (eg. 200 km by 200 km).

- Must have temporary storage capability for 2-3 days of imagery and ice maps.

- Must be interfaced by high speed data bus to SCIP, NAVSS and REMSCAN interface.

- Must be user friendly.

- Will be distributed throughout REMSCAN infrastructure depending on user preference and system configuration (i.e. elements of RSS will exist at REMSCAN Central, the Regional Centres and the vessels).

- RSS will not duplicate functions already performed on individual vessels (i.e. RSS workstations would not be installed on vessels equipped with MIDAS or equivalent, however, MIDAS would interface to RSS).

- RSS would not normally have its own sensor resources but would subscribe to services provided by other agencies or contractors.

- Must have reliability, availability, maintainability, factors approaching 98 percent.

7.7 Navigation (NAVSS) Subsystem

7.7.1 Hybrid Navigation Subsystem

The major regulatory requirements covering navigation of ships of gross tonnage greater than 1600 tons are detailed in the following documents:

- Arctic Waters Pollution Prevention Regulations
- Arctic Shipping Pollution Prevention Regulations
- The Canada Shipping Act
- Navigable Waters Protection Act
- Navigation Appliances Regulation

Vessels transitting the Northwest Passage must meet regulations covering zones 2, 6, 9, 10, 11, 12 and 13 (see Figure 1). If these vessels meet the minimum regulations of the Arctic Shipping Pollution Prevention Regulations, they will be equipped with the following navigation gear:

- Two gyros
- Two marine radars
- Two echo sounders
- Navigation instruments and publications necessary to determine compass error and positions by astronomical means
- Facsimile terminal

In addition to these equipments, many vessels (in particular the high technology types) will have some or all of the following:

- Advanced marine radar (AMR)
- Satellite navigation (SATNAV) receiver
- Integrated navigation system (INS)
- Subsurface scanning sonar
- Precise navigation aids (typically for channel navigation)
- Automated or digitized hydrographic charts

The functional concept outlined in Section 5.4.3 called for shipboard navigation components to be outside REMSCAN in the same manner as remote sensing sensors. Thus the hybrid version of REMSCAN NAVSS leans closer towards the totally shipboard scenario than to the centralized facility. Again, this is consistent with the requirement for REMSCAN to be complementary to ships' autonomy, rather than attempt to compensate for the lack of it.

7.7.2 Tasks of Navigation Subsystem

Vessels will be autonomous as far as the provision of most tactical and close tactical navigation requirements are concerned. The role of the REMSCAN NAVSS can be described as follows:

- To provide georeferencing, in absolute parameters to all remotely sensed data backhauled to REMSCAN
- To provide strategic navigation information to client vessels

- To enhance tactical navigation accuracies where necessary to ensure safety and efficiency in ice infested waters
- To supply navigation data to the vessel traffic management function of the System Control and Information Processing Subsystem (SCIP).

The tasks of the NAVSS can be summarized as follows:

- Receive data from ships navigation system (heading, speed, position etc)
- Receive relative position information from RSS
- Receive relative position information from appropriate externally referenced navigation system
- Convert relative position data to absolute coordinates
- Assign absolute geo-referenced parameters to topographical ice and land features obstacles (features) identified by RSS
- Establish navigation aids where otherwise not provided (i.e. for marking underwater hazards)
- Communicate with other REMSCAN subsystems, notably, the SCIP for route optimization, RSS for georeferencing, and interfaces and communications subsystems for receiving and sending navigation data.

7.7.3 Shipboard Tactical Environment

As stated earlier, from a tactical standpoint, vessels will be more-or-less self-sufficient for navigation purposes. SAR imagery downlinked directly to the vessel will be referenced to the aircraft INS. The vessel orients itself relative to the imagery either by finding itself on the picture or by identifying ice or land features relative to its own position. Continuous plotting of vessel position and identified features on a marine chart (conventional or digital) allows the navigator to pick his way through an ice field or travel from lead to lead. Periodic satellite fixes allow an independent check of the ship's position and dead reckoning is done between satellite fixes.

Such a system is suitable for a single vessel transmitting waterways, however, it has several drawbacks when consideration is given to sharing remotely sensed ice information with other vessels. First of all, information collected aboard ship is referenced relative to the vessel; its accuracy is dependent upon the inherent accuracy of the vessel's integrated navigation system. Accuracy of data collected in this situation can be degraded by the following:

- SATNAV: inherent system error, in particular, due to lack of suitable fixes at latitudes above 70°N.
- : dead reckoning error of .2 nautical miles for each knot of unknown velocity.

  INS : excessive gyro drift at latitudes N of 70°.
  : accelerometer, torquor noise, vibration, etc, especially on ice breakers.
- SAR imagery: INS error
  : uncompensated aircraft motion (yaw, pitch, roll)
  : imagery stretch, foreshortening

- Marine Radar Processing: difficulty in defining boundaries and precise targets of collated radar imagery

Generally speaking, the combined position error of data collated aboard ship will be approximately 1 nautical mile. This means that even though a vessel collecting data can provide most of its own tactical support to within 500 metres relative to itself, that same data can only be absolutely referenced to within 1850 metres. All other users of this data must accept the reduced accuracy which likely would not be consistent with their individual navigation needs or capabilities especially when these other users encounter the same difficulties in fixing their own position.

The REMSCAN NAVSS offers the means for extracting the best possible accuracies of individually collected data sets through collation, analysis and synergism. A straightforward example of this is the ability to mosaic SAR imagery which overlaps with other imagery (in time and/or space) to establish features of known (absolute) position. Another method would be to reference all data to an external navigation/positioning system possessing inherent accuracy consistent with the most stringent requirements. Developments such as NAVSTAR GPS and improvements in ships' INS will solve much of the problem, however, such developments may be as far off as 1990 (for GPS) and not all vessels will be equipped with state-of-the-art INS. Even a convoy of vessels following a suitably equipped escort requires absolute geo-referenced data when conditions preclude following close behind the lead vessel.

Furthermore navigation of narrow channels or shipping corridors requires more precise accuracies than shipboard navigation systems can be relied upon to provide. Underwater scanning sensors will go a long way toward avoiding collisions with sub-surface obstacles such as pingos or submerged ice. However, these systems will be range limited, and avoiding charted hazards by utilizing precise navigation system is a fundamentally sound approach.

REMSCAN NAVSS, therefore, would provide these basic capabilities:

- Georeferencing of collected data and topographic ice features
- Precise navigation of narrow channels
- Underwater ice obstacle avoidance
- Position monitoring of vessel traffic
- Primary positioning of static platforms

7.7.4 Summary of NAVSS Requirements

- Must receive position data from all available sources including shipboard sensor and externally referenced radio positioning system.

- Must compare, collate, and confirm position data to ensure accuracy and consistent reporting of ice target and vessel locations.

- Must perform georeferencing function to provide absolute positioning of vessels, obstacles, landmarks, ice fields, leads etc.

- Must interface to RSS or marine radar to allow operator to assign targets for georeferencing.

- Must accept output from RSS (maps, charts, targets) and produce georeferencing data in a format suitable for handing back to RSS. (Note the NAVSS produces only strings of data which would normally be displayed in conjunction with the output of the RSS, not by themselves.)

- NAVSS would not normally have its own shipboard sensors but would acquire data from systems such as INS, marine radar, beacons, etc. LORAN C is identified as a means of providing coverage in specific regions requiring accurate navigation. Such an externally referenced navigation system would be provided by REMSCAN infrastructure or, alternatively, as a parallel support activity under the auspices of REMSCAN.

- Must have reliability, availability and maintainability factors approaching 98 percent.

7.8 Communications Subsystem Requirements

7.8.1 Constraints on Arctic Communications

Realistic requirements for REMSCAN communications are largely governed by the extreme conditions encountered in the Arctic such as high latitude, sparse, fragmented population, and vast expanse. The effects of these conditions on available communication technology and services are outlined below.

a) Satellites

The Anik B and D 6/4 GHz services provide the greatest satellite coverage in the Arctic. Above approximately 80°N latitude, the earth station elevation angle is close to 0°, requiring larger antennas to overcome fading. Anik 6/4 earth stations cannot be practically located on vessels, especially those navigating through ice due to the difficulty of stabilizing a large antenna under very dynamic conditions.

Anik C 14/12 GHz coverage is presently limited to Southern Canada including east and west coast offshore areas and parts of Hudson Bay. Experiments conducted by the Canadian Petroleum Association in conjunction with the CRC have shown that stabilized Anik C platforms perform well when located on stationary semisubmersible drilling rigs. Further research is required to determine the performance of these platforms on more dynamic vessels such as ice breakers.

The Innarsat System provides relatively inexpensive offshore satellite communications. A nominal coverage gap exists in the central Arctic between the Pacific and Atlantic satellite patterns, although vessels have successfully used the service as far north as Resolute. Arctic coverage could be substantially

improved beginning in 1988 when the next generation of Innarsat satellites are launched. Data speeds are normally limited to 2.4 KBS over voice grade channels. Innarsat also offers a 56 KBS service that presently requires the data to be downlinked through one of the American coastal gateways and then backhauled to Canada, a very costly undertaking.

MSAT service is slated to begin in 1989. Coverage is expected throughout the North West Passage with ground station antenna elevation angles of 5^{0} to 10^{0} typically. The maximum data rate will be limited to 2400 BPS. The DOC discourages full period service owing to its detrimental effect upon traffic handling ability for occasional users, for which MSAT is intended.

b) Common Carrier Services

The remoteness of Arctic repeater sites frequently results in prolonged outages, occasionally lasting up to several days. This, combined with the large number of microwave radio hops between the Arctic and Southern Canada, makes data communications particularly poor.

There are no public packet data networks in the North. Leased lines have been used for dedicated data circuits up to 9.6 KBS but at considerable expense. Oil companies with regional centres in the Tuk area have overcome these problems by installing satellite earth stations at their camps to provide direct data links with Calgary.

Telephone service via terrestrial microwave or satellite earth station is limited to the larger communities while VHF and HF radio telephone service is only available along the Mackenzie River and in the offshore Tuk area.

c) Canadian Coast Guard Ship to Shore Communications

This is a voice network providing command and control to the CCG fleet, communications for commercial vessels and listening stations on international safety frequencies. The network requires a high degree of manual intervention by CCG radio operators. Some stations do not have full 24 hour service, while others are operated only in the summer navigation season.

The northern segment of the CCG network operates primarily at medium and high frequencies. VHF coverage is poor or non existent. Primary text and data capability is via facsimile.

d) Terrestrial Radio Coverage

The more important factors governing radio coverage are antenna elevation, frequency band, transmitter power and atmospheric conditions. Useable coverage is generally restricted to the following ranges:

MF - 300 miles
HF - 600 miles
VHF - 50 miles
UHF - 40 miles

e) High Bandwidth SAR/SLAR Downlinks

Operational requirements usually require that omnidirectional low gain antennas be used on the aircraft and at the ground station. The resulting link fade margin is therefore low resulting in path fading at longer ranges. The range is ultimately limited by the radio horizon to around 200 nautical miles.

7.8.2 Technical Requirements and Design Objectives

a) Radio and Satellite Coverage Area

Each regional centre will provide communications to REMSCAN subscribers within its boundaries. The choice of communications media will depend upon range and bandwidth requirements. Users will typically only communicate with the REMSCAN Regional Centre for the region they are within or with their own regional base. Communications will not normally occur between a vessel in one region and another regional centre. Communication responsibilities will be handed on to the adjacent region when the vessel crosses a regional boundary.

Information from REMSCAN Central will be distributed to vessels by direct broadcast using MSAT or long range HF radio.

b) Data Communications

The overriding requirement for the foreseeable future is that data rates for long haul networks in most cases be restricted to 2400 BPS thus ensuring that REMSCAN can use a variety of communications media. Data at this speed can easily be carried by dedicated leased lines, switched voice network modems, microwave carrier and narrowband FM radio from the VHF band on upward. MSAT will also operate at 2400 BPS thus permitting a simple transition to this service when it becomes available in 1989. Second generation MSAT satellite channels, available in the mid to late 1990's, may possibly operate at higher speeds, say 9600 BPS. A HF modem capable of performing reliably at 2400 BPS in the skywave mode will likely not be available before the mid 1990's, although units are presently available that operate at 300 BPS. Multiplexing can be used if warranted to pipeline high volume traffic between REMSCAN Central and Regional Centres. Specific requirements and objectives for data communications are outlined below.

- Data Volume: The volume of data transferred between sites will be minimized by processing close to the source.

- Data Rates: Links between Regional Centres and vessels will not exceed 2400 BPS. Communications confined to a vessel can

occur at any feasible data rate as can SAR/SLAR air to ground links.

Links between REMSCAN Regional Centres and user's regional centres will be no faster than 2400 BPS.

Links between Remscan Central and Regional Centres will be at least 2400 BPS. Such links will likely be provided by satellite hence large bandwidths will be readily available.

- Thoughput Delay: Throughput of abstracted imagery from vessels to REMSCAN Central or between vessels and Regional Centres must not be delayed by more than 15 minutes from start of transmission.

- Reliability: Data links must be available for at least 23 hours per day or 96% on a long term basis.

- Existing Networks: The REMSCAN Network must be overlaid whenever possible on existing networks.

7.9 System Control And Information Processing (SCIP) Subsystem Requirements

Several subsystems have been identified:
- Assembly
- Evaluation
- Integration
- Forecasting
- Dissemination
- Archiving

Spread across these are control functions to ensure that information exists and is available as required by each subsystem.

7.9.1 Assembly

This is the standardization of incoming data and its initial correlation with existing data. Sources of data are listed elsewhere in this document; the most common will be:

Satellite scans	Large area, low resolution
Meteorological reports	Large area, very low resolution
Airborne scans (reduced SAR)	Small area, medium resolution
Visual reports	Very small area, high resolution (but low precision)

Interpretation and geographic registration of the data are functions of the remote sensing subsystem, and place no burden on the SCIP package.

The assembly operation inserts the received data into the database in preparation for use by other subsystems.

As an aid to understanding, the following structure is suggested for the database (see Figure 11). This is not intended as a design proposal; the structure suggested is based on the assumption that the ice map database will be stored as a collection of small areas ("tiles") perhaps 25 Km square, indexed by location. Other, low resolution data (e.g. meteorological) is a feasible means of implementing the ice map database, no attempt has been made to determine whether it is optimum.

Each item has a timestamp, so that outdated information can be immediately recognized. The different types of data are separated to minimize storage used, since they all have different resolutions. The ice map is expected to dominate storage use; with approximately 6 million Km^2 to be represented at a resolution of 200 m (which at 4 bits per pixel will require 75 Mbytes) and an even larger surrounding area at a lower resolution (probably requiring more than 100 Mbytes).

The structure shown does not specify the resolution of the image, so this could vary from tile to tile, but data processing would probably be most efficient if all tiles were the same size and shape.

In order to represent features too small to appear at the normal resolution of 200 m, but which are nevertheless significant, such as leads and pressure ridges, a series of "significant feature" records could be appended to the tile, giving the width, orientation, and length. These records could also be used to indicate the location of uniquely identified floes or bergs, for precise tracking.

Incoming data is expected at a rate in excess of 20 Mbytes per day, and the arrival rate will be very non-uniform. Most of the data will be airborne SAR scans with a resolution of approximately 1 Km. About 3 Mbytes/day will be reduced SAR data (resolution 200 m). Meteorological data will also arrive in bursts, but the average rate will be much lower than that of the ice map data.

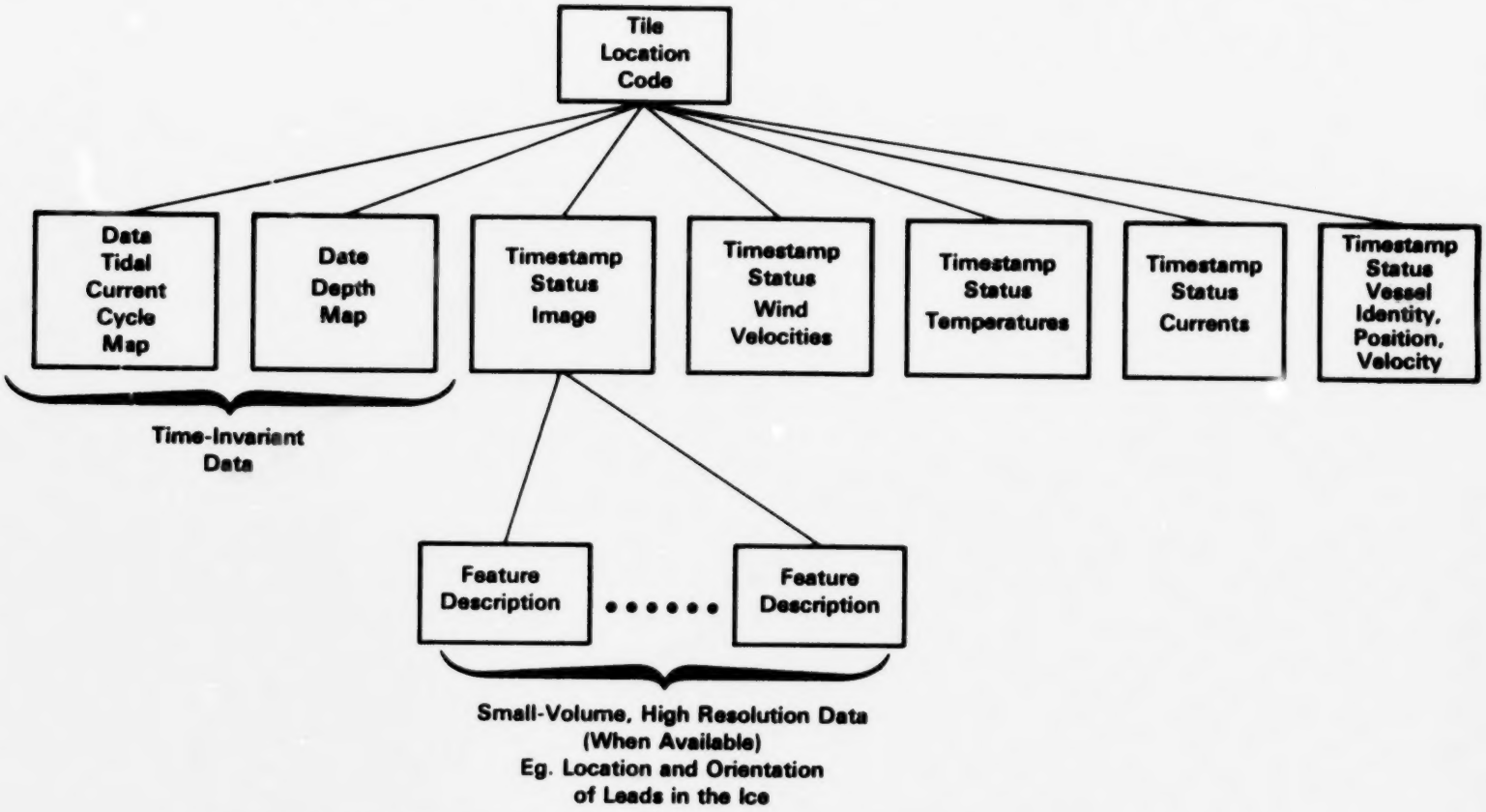
7.9.2 Evaluation

This subsystem would conduct reasonableness checks on data recently added to the database by comparing it with previous, surrounding, and expected data for that location, and where appropriate with feasible maxima and/or minimise.

Data considered improbable or impossible would be brought to the attention of a human operator for confirmation or correction. Data found to be untrustworthy could be deleted, or it might merely be flagged so that it would not be used until confirmed or corrected.

Once new data has been confirmed, old data for that location can be deleted, though at least one previous observation needs to be retained for the integration subsystem.

It is also possible that if intermediate steps are retained from the calculation of a forecast, fresh data can be compared with the appropriate time period from the forecast, enabling each detection of deviations from the prediction.


Tile Location Code
Data Tidal Current Cycle Map
Date Depth Map
Timestamp Status Image
Timestamp Status Wind Velocities
Timestamp Status Temperatures
Timestamp Status Currents
Timestamp Status Vessel Identity, Position, Velocity
Time-Invariant Data
Feature Description
Feature Description
Small-Volume, High Resolution Data
(When Available)
Eg. Location and Orientation
of Leads in the Ice
'Status' Indicates to What Extent the Data Has Been Verified, or That It Is a Forecast

CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: IMAGE DATABASE (SUGGESTED) STRUCTURE FIGURE No. 11

7.9.3 Integration

This subsystem would attempt to correlate the maps from different sensor types, where more than one sensor had scanned a given area. By combining observations at different wave lengths for example, it may be possible to automate some portions of the interpretation process.

7.9.4 Forecasting

This subsystem will examine the current ice map, and in conjunction with current and predicted environmental data will attempt to predict the ice map at a specified future time (usually 12 or 24 hours in advance). Predictive models of this kind work best when considering as large an area as possible - in this case, the entire arctic - so it has been assumed that forecasting will be performed at the REMSCAN central facility, with the possible exception of a summer ice model. This is a limited model for the purpose of predicting the motion of individual floes and bergs. It would still require a substantial database of environmental information, and also significant processing power. If implemented at Regional Centres or onboard major vessels, it would represent a significant increase in the computing capability needed by these locations.

Where the position of vessels in the forecast area can reasonably be predicted, a hazard check can be performed, taking into account the ice-performance capability of each vessel. Depending on the sophistication of the model used, the computational requirements should be easily within the capacity of a regional centre. It is not anticipated that individual vessels will need or want automated assistance for this task. The information would mainly be of use to the staff at a regional centre, to draw to their attention the possibility that a vessel may encounter difficulty before it occurs, enabling them to issue a warning or advisory if appropriate.

A major spin-off from the forecasting subsystem is the possibility of performing route optimization calculations for vessels in the forecast area. This has the potential of very large economic benefit, but also has the potential of vastly increasing the storage and processing resources consumed by the REMSCAN system.

The reason for this is as follows: In order to determine the optimum route for a vessel, the progress of the vessel must be projected along each plausible route, taking into consideration the performance capability of the vessel, and the ice conditions it will encounter at each point on each possible route, at the time it would get there. In order to permit accurate modelling, the forecasting subsystem would need to 'leave behind' intermediate forecasts at (say) hourly intervals covering the likely navigation routes. It would also probably be necessary to forecast up to several days in advance to enable the best route to be selected as far ahead as possible. The necessity to store the intermediate forecasts could be eliminated if the route optimization calculation were integrated with the forecasting model, but this would increase the difficulty of software development significantly, and if

done as a modification to a working forecasting model, would create he possibility of introducing errors into that model.

Modularizing the software requires the storage of freq nt intermediate forecasts, as indicated above, but each would need to c er only a fraction of the total forecast area, so the total sto ge requirement might be only a small multiple of an individual forec t. Moreover, as indicated in the evaluation subsystem (7.9.2), he intermediate forecasts can be put to additional use in helping to ve fy incoming data, and at the same time providing a running check on he accuracy of the forecast.

To prepare a forecast, a small file of location-indepen nt environmental parameters must be provided, such as the relative eff ts of wind and current on ice of different thicknesses, probable s ar strengths of ice of different types, etc. As indicated in the sugge ed database structure, there will also be a number of location-depen nt parameters. Whether or not route optimization is to be performec a file of ice-performance characteristics for each vessel in the fore st area will be needed so that appropriate hazard warnings may be iss d. As a minor point, it would probably be advantageous to retain as ch flexibility as possible in the hazard evaluation software, so as to pe with vessels with unusual ice-performance characteristics (g. submersibles and hovercraft).

Meteorological forecasts will also be required by ship's mast s, and although it is not anticipated that REMSCAN will prepare ch forecasts, it will be using them, so could include such information th ice forecasts if desired.

The final type of forecasting likely to be asked of REMSCAN is il spill modelling. All the information needed to prepare such forec ts is already present in a working system, as soon as the amount, type, nd location of the spill is known. A suitable program exists at present

7.9.5 Dissemination

To be useful, data on the present and predicted conditions in ny area must be distributed to vessels in or about to enter that a a. Some vessels will be able to receive detailed color imagery, w le others may have only a black and white facsimile receiver. Some ay have only teletype and/or voice communications.

This subsystem must prepare versions of the forecasts suitable or transmission to each vessel requesting one, and ensure that reception is confirmed. A file will be required indicating what type of informa on can be handled by each vessel. This could be conveniently appende to the ice-performance capability file.

When a request for data is received, this subsystem must exa ne the database to determine whether that information is alr dy available. If it is, a reply can be sent immediately. If it is t, the control subsystem must be invoked to schedule the neces ry activities to obtain the information. As part of the positive-resp se

Philosophy the authors envisage for REMSCAN, a reply would then be sent to the requesting vessel indicating when the information would be available.

7.9.6 Archiving

A record of each nowcast and forecast issued should be retained, to provide an historical database of the entire area. This can be used in an off-line mode to revise environmental parameters used in preparing forecasts, by comparing forecasts with the actual situation as it turned out.

Less frequently, perhaps weekly, a complete dump of system software should be performed. It is probable that at least for the first few years of a system of this magnitude, software will evolve quite rapidly. In such an environment, frequent backups are essential; however the volume of data is likely to be small by comparison with the maps archived.

Also, all activities performed by and for the system (SAR flights, reception of weather forecasts, etc.) should be logged.

7.9.7 Control Functions

This is essentially an activity scheduling subsystem, with monitoring to ensure that activities external to REMSCAN are performed as intended.

To do this, the subsystem will need detailed lists of the step-by-step actions required to complete each data gathering or processing operation, with the duration of each, and linkages indicating which activities are dependent on the completion of others. The requirements for this subsystem cannot clearly be defined at this time, but could include the ability to perform critical-path analyses and/or prioritization of resource allocation. Further study is required to establish the necessary function in more detail.

A positive-response philosophy is envisaged for this subsystem, in which the control subsystem will request confirmation of the completion of each activity, so that delays become known at the earliest possible time.

7.10 Interface Requirements

REMSCAN will be an evolving network whose interface protocols must adapt to future, possibly unforeseen requirements. The interfaces chosen must not be unique to REMSCAN and wherever possible should be built upon existing or planned internationally accepted standards. General requirements for such interfaces are listed below:

- Compatibility: The REMSCAN interfaces and associated protocols must support communication between many dissimilar processors and terminal equipment.

- Robustness: The protocols must be adaptable to noisy, fading channels (HF), to time delayed channels (satellite), as well as solid voice grade channels (VHF).

- Access: The communications system must be highly automated for easy access by unskilled operators. To this end, the network must automatically reconstitute itself when disabled by equipment or propagation outages.

- Protocol Structure: A layered network architecture is required in order to construct a system as vast as REMSCAN.

- Handshaking: Protocol handshaking and other synchronization activities must be kept to a minimum.

- The network must include procedures for initialization, routing, access control and flow control.

- The network should support dedicated, full period virtual circuit communications as well as packet switching.

8.0 REMSCAN DESIGN

In this part, the REMSCAN design is developed at the subsystem level in sufficient detail to permit costing. Estimates are given.

8.1 REMSCAN System Block Diagram

Figure 12 shows the overall REMSCAN system block diagram, consisting of:

- REMSCAN Central
- A representative Regional Centre
- A representative Major Vessel

Also indicated are a SAR aircraft downlinking imagery to the major vessel, which is in turn feeding processed information to client ships (e.g. a convoy). Note that for reasons of clarity, the full block diagram corresponding to the system configuration of Figure 9 has not been shown. In most cases considered in the scenario of Section 6.1, client vessels, i.e., low-tech vessels, would receive information from one of the Regional Centres which would themselves be direct recipients of downlinked imagery.

8.2 Remote Sensing Subsystem Block Diagrams

8.2.1 RSS Information Flow

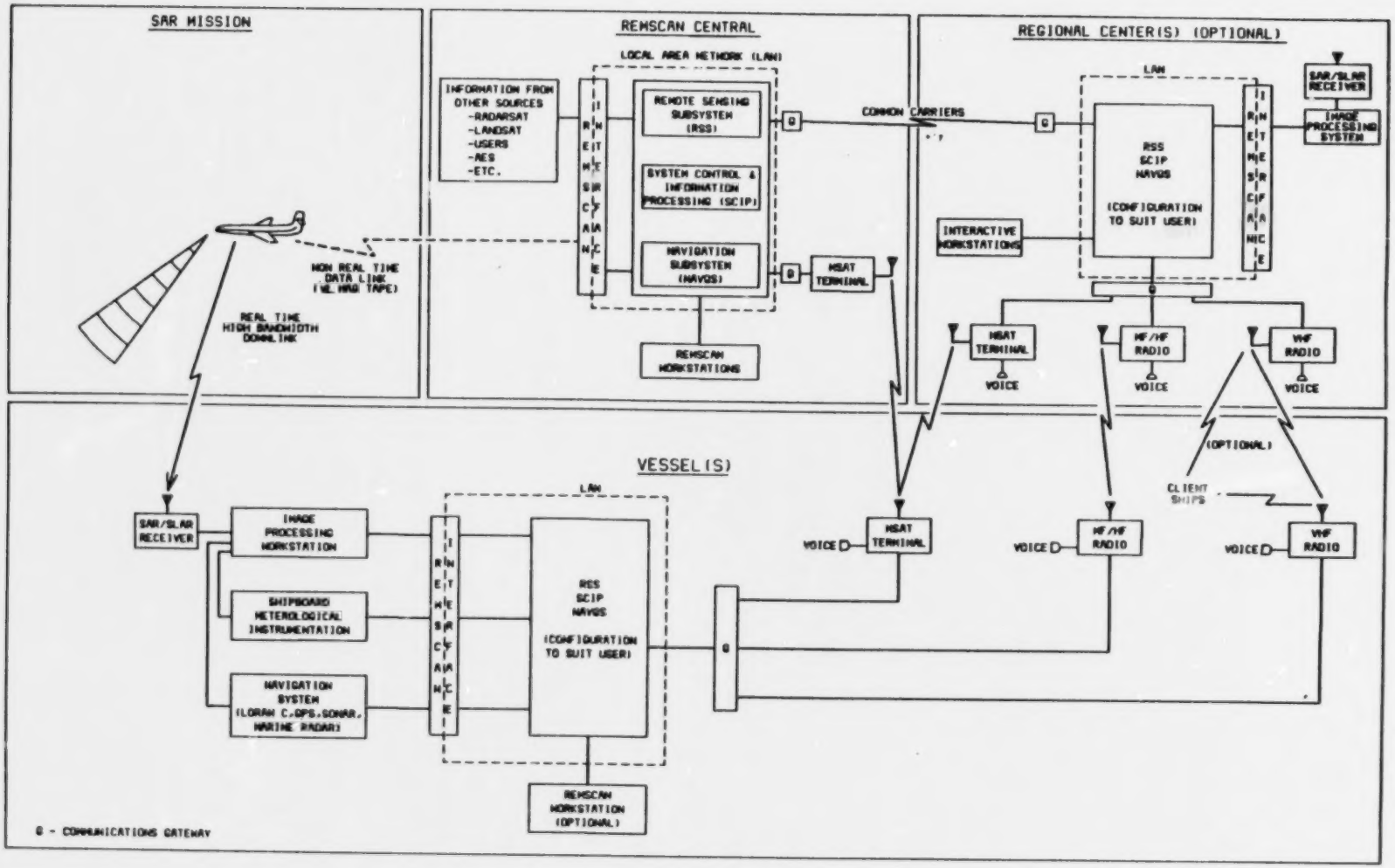
Figure 13, depicts the information flow of remotely sensed data. Note that complete tactical data sets are acquired and exchanged at the ship level and that synthesized (abstracted) data sets flow between the ships and REMSCAN Central. REMSCAN Central also receives data from all other available sources in order to provide strategic information to vessels which request it as well as tactical information for static platforms or vessels which do not have high technology sensors or dedicated airborne surveillance.

8.2.2 Shipboard RSS Block Diagram

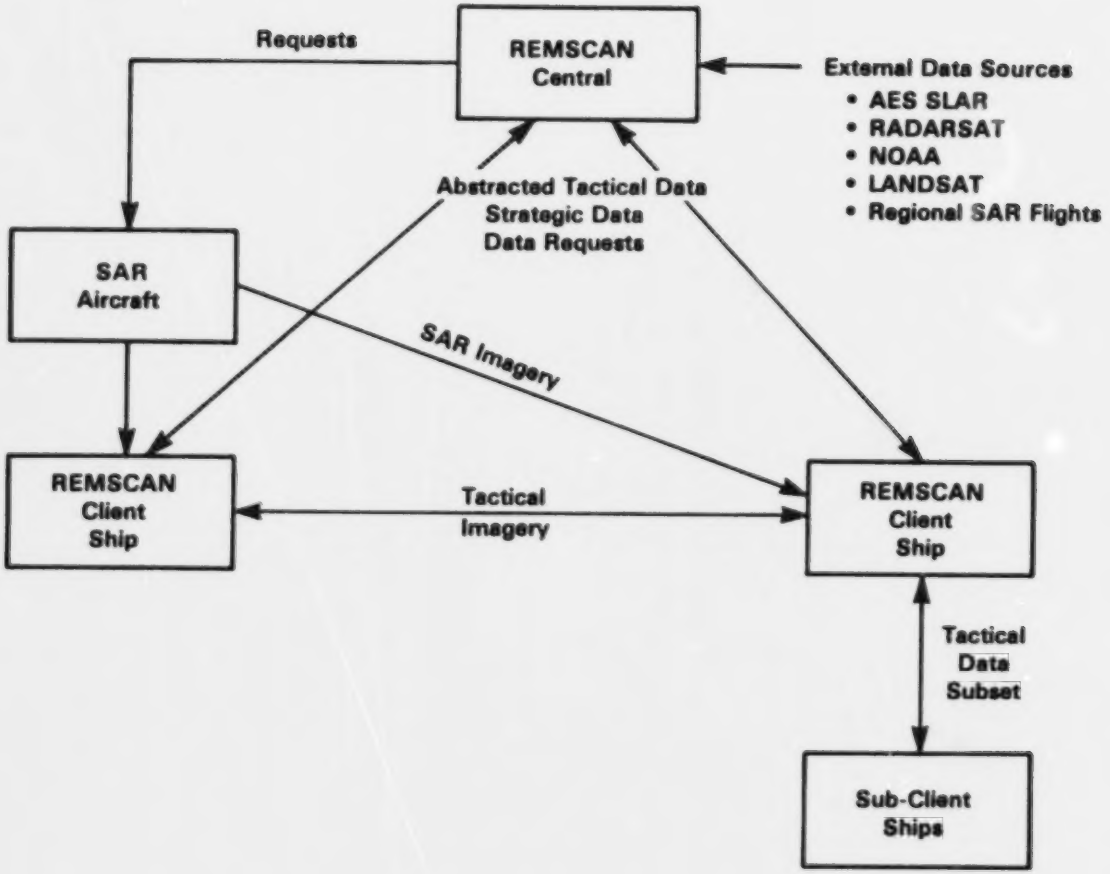
Figure 14 shows both the client owned shipboard components (e.g. MIDAS and those interfaced to MIDAS) and the REMSCAN component of the RSS. The tow are shown separately because the REMSCAN component remains unchanged with varying complexities of client component (i.e. REMSCAN Communications Subsystem could be a radio facsimile channels). However, in the high technology case shown, the REMSCAN component would physically be a module of the clients MIDAS in order to avoid duplicating the display requirements. For classification, a separate REMSCAN display is shown as optional.

8.2.3 REMSCAN Central RSS Block Diagram

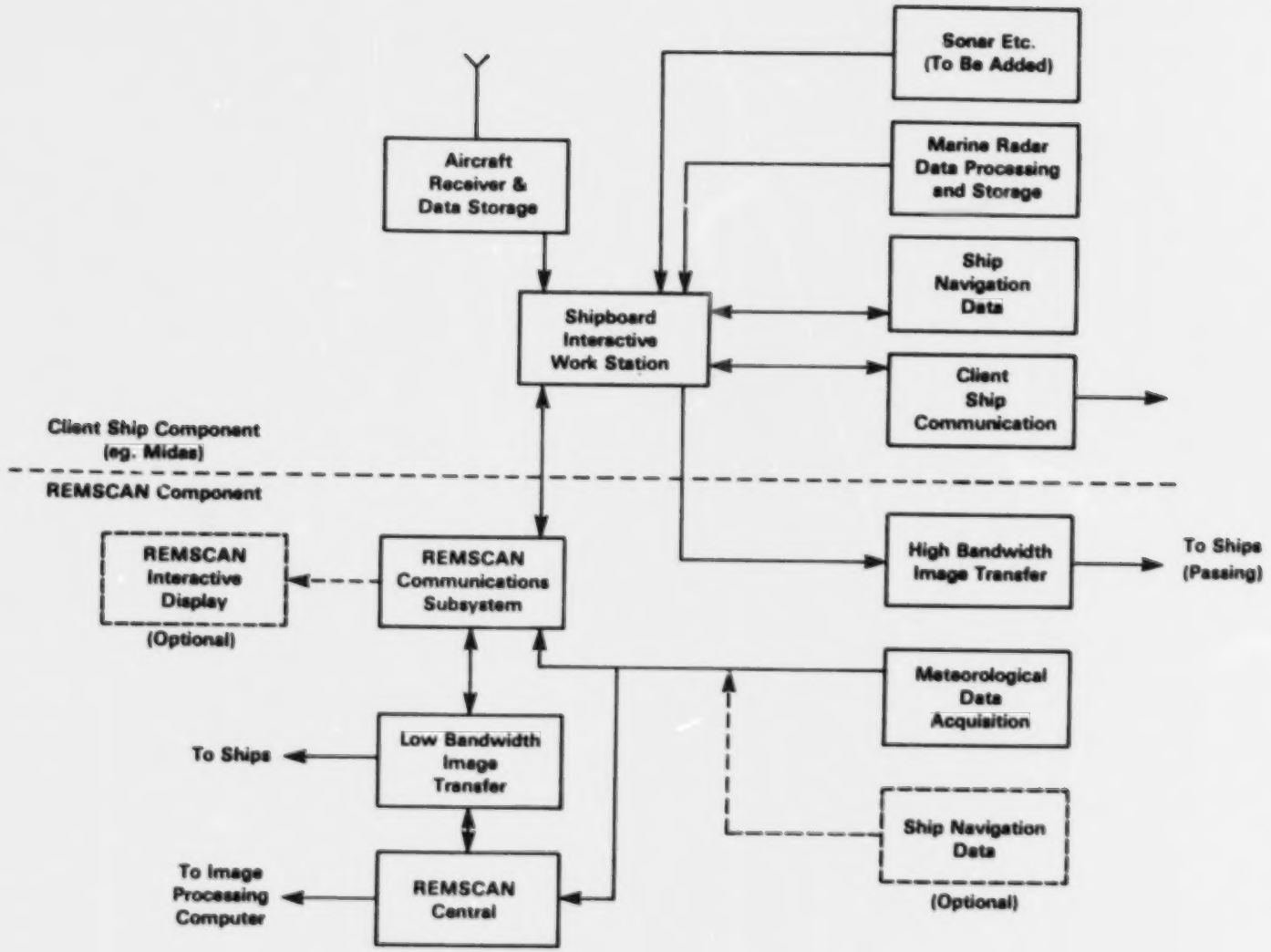
Figure 15 illustrates the composition of the RSS at REMSCAN Central or at a regional centre, as referred to earlier in the report.



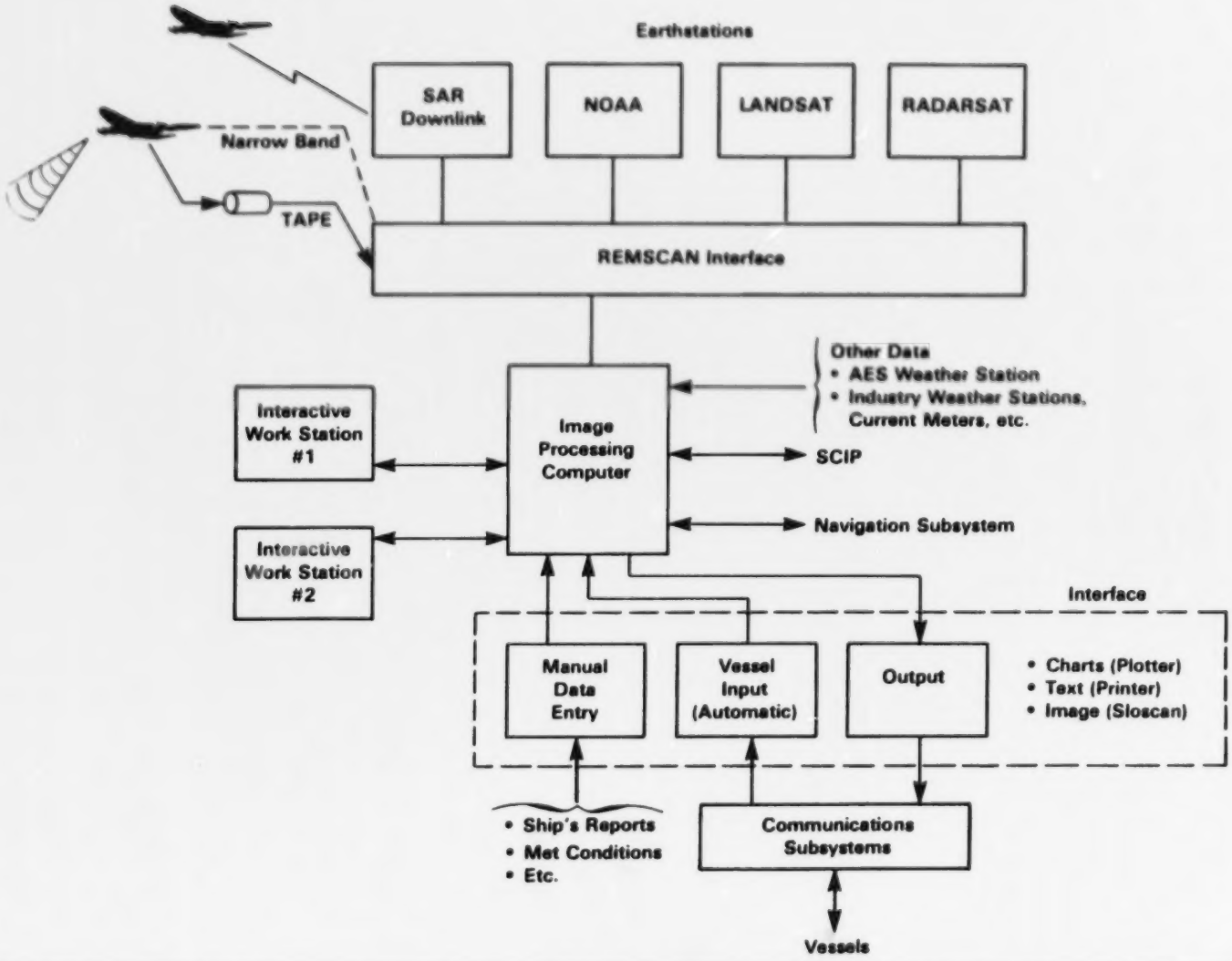
CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN SYSTEM BLOCK DIAGRAM
		FIGURE No. 12



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN REMOTE SENSING SUBSYSTEM INFORMATION FLOW
		FIGURE No. 13



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: SHIPBORNE REMSCAN REMOTE SENSING SUBSYSTEM BLOCK DIAGRAM
		FIGURE No. 14



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN CENTRAL REMOTE SENSING SUBSYSTEM
		FIGURE No. 15

8.2.4 Cost Schedules

8.2.4.1 Shipboard Hardware Costs

Low Technology - nil (all components in place)
High Technology (as per diagram)
(exclusive of communications interface and equipment)

REMSCAN Interactive Display	$ 30 K
Low Bandwidth Image Transfer	5 K
Meteorological Data Acquisition	5 K
Ship Navigation Data Acquisition	5 K
High Bandwidth Image Transfer (Downlink Transmitter/Receiver)	75 K
	$120 K

8.2.4.2 REMSCAN Central Hardware Costs

Earth stations - nil (REMSCAN facility located with AES)
NOAA, LANDSAT, etc.

SAR Downlink	60 K
Interactive Work Stations	100 K
Image Processing Computer	1,000 K
Manual Data Entry	5 K
Data Input Device (Automatic)	200 K
Output Device	50 K
- chart recorder	
- printer	
- SLOSCAN	
	$1,415 K

8.2.4.3 Development Costs

Prototype	3,000 K
Software	3,000 K
	$6,000 K

8.2.4.4 Operating Costs

Personnel (4 personnel x 3 shifts x 365 days) 4389 mandays per year @ $400	1,750 K
Equipment Maintenance (Operating Costs) (based on VTMS, North Vancouver)	2,000 K
TOTAL	$3,750 K/yr

8.3 Navigation Subsystem (NAVSS) Description

NAVSS will consist of major components as follows:

- Shipboard interface to collect navigation and position parameters (this may be a function of the REMSCAN Interface)

- Central processor for comparing and collating relative positi ı data
- Link to the RSS as it will be the RSS Interactive Works ıtion, manned by an operator, which selects and identifies featu s for georeferencing
- Externally referenced navigation chain (where requir for continuous coverage, i.e. for narrow channel navigation)
- Link to SCIP for control and production of route optin zation information
- Markers for fixed underwater obstacles
- NAVSS Display (likely integrated with other displays)
- Interface to hydrographic data display (conventional marin chart or automated display). (Note that hydrographic informat on is provided by systems external to the NAVSS.)

The externally referenced navigation system would impro e the accuracy of the data collected aboard ship, which directly suppo ts the ship's tactical navigation, as well as indirectly improving the a curacy of geo-referenced data derived from other sources. Also, the nk to the RSS may be paralleled to non-REMSCAN shipboard image pro essing components such as MIDAS so that all georeferencing is performed aboard ship. This situation may be appropriate for vessels which are re eiving dedicated SAR and regional SAR support.

8.3.1 Shipboard NAVSS Components

A precise navigation system like that developed by Dome Pe roleum for Beaufort Sea navigation and positioning operations would ser : as a basis for the shipboard NAVSS. A description of this system is a tached as Appendix C, however in general, this system interfaces to the ship's navigation system and any externally referenced systems such as ATNAV, LORAN C, etc. to provide continuous alphanumeric and colour raphic representation of the vessel's position relative to its various ir uts.

These systems are in common use for harbour navigation and o fshore survey and are available in enhanced versions for integrati with advanced marine radar (AMR). Integrated navigation and display ystems are becoming more available commercially and several sho d be investigated for suitability to the NAVSS. Brochures are atta ed at Appendix C of the following equipments:

- Texas Instruments Integrated Marine System
- Texas Instruments LORSAT Navigation System
- Navigation Sciences Viewnav Master Marine
- Racal Marine Prototype Integrated Electronics
- Qubit Trac IV

As stated previously, if a vessel had enough input paramet s (in the form of SAR data, visual reconnaissance, external navigation chain, etc.) it is possible that all georeferencing could be performed aboard the ship and additionally, be able to service any client vessel i.e. a convoy) itself. For most vessels, however, sufficient data would ot be available, in particular for georeferencing of strategic data, d the processing function would normally be done at a central f cility (REMSCAN Central or Regional Centre).

Hydrographic information would be provided in conventional form (marine chart) or overlaid in a digital format on the navigation display. This integration could be taken a step further (although unlikely in the near term and not until studied thoroughly for information overload problems) by overlaying position, channel, hydrographic and ice data on the same display or set of displays. It is envisaged at this time that the NAVSS will have a separate navigation console in close proximity to the radar displays, if not integrated with the radars.

If georeferencing is performed aboard ship, a small array processor unit would be required to manipulate and correlate positioning data of those features specified by MIDAS or the RSS, whichever is servicing the vessel's tactical or strategic requirements. A representative shipboard NAVSS block diagram is shown in Figure 16.

8.3.2 Externally Referenced NAVSS Components

Several possibilities exist for the externally referenced component of the NAVSS.

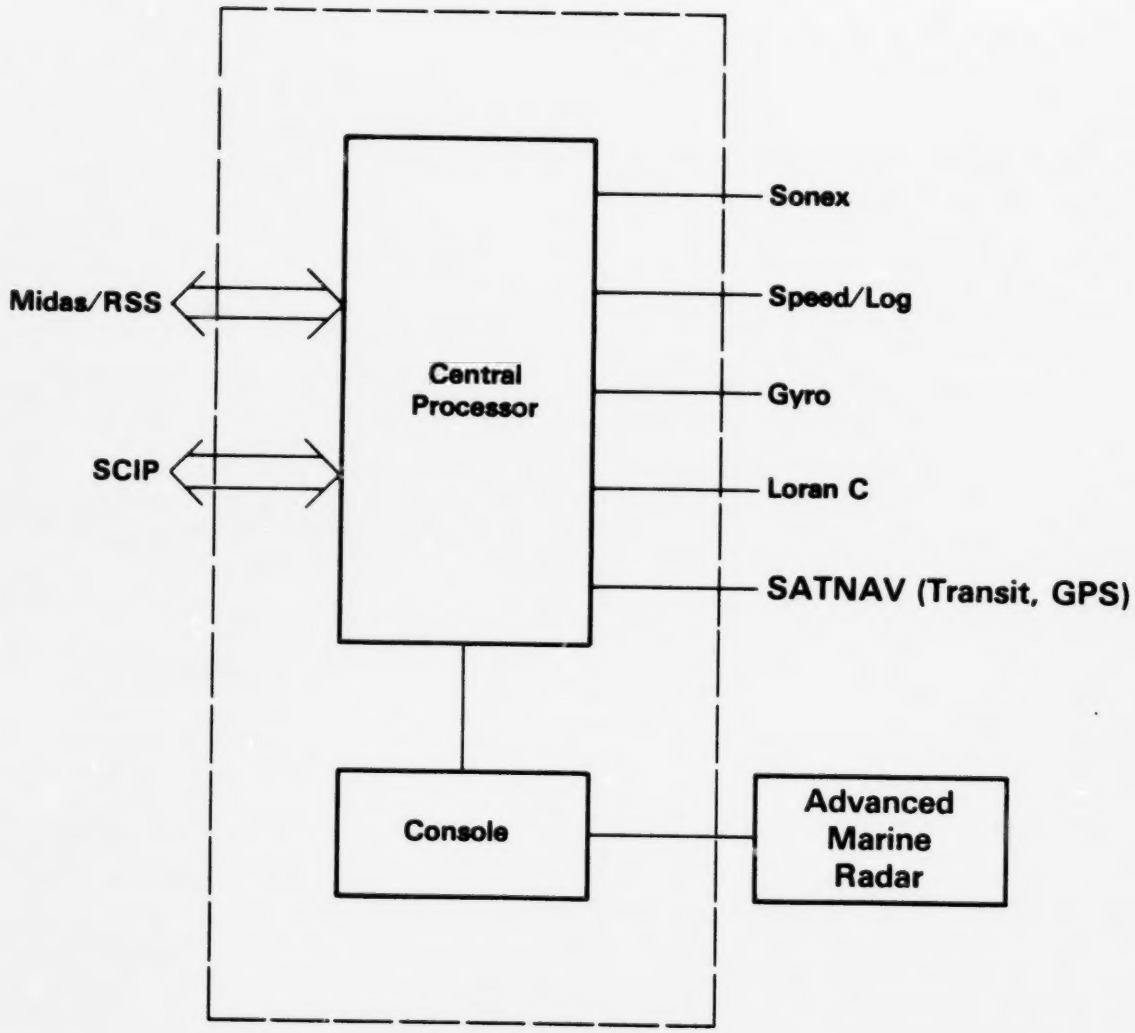
- NAVSTAR GPS to provide universal coverage to an accuracy of 100-500 metres
- LORAN C (or equivalent) to provide complete or semi-continuous coverages through Northwest Passage (15-400 metres accuracy range dependent)
- RACONS (radio navigation beacons) to mark prominent land features (50 metres accuracy)
- Acoustic transponders to mark sub-surface obstacles such as pingos, submerged ice, berms etc (5-50 metre accuracy - range dependent)

Navstar GPS is not expected to provide adequate coverage in Arctic waters before 1990. Once established it will provide georeferencing for all data collection except for that where more precise positioning is required, notably hydrographic and seismic survey and channel navigation. GPS will be compatible with NAVSS; however, for the time being it will not be considered as a usable alternative, and in any event, will be cheap enough eventually to augment or replace systems which precede it.

The preferred solution for implementation prior to 1990 is a mix of the remaining three: LORAN, RACONS and acoustics. RACONS and coded acoustic transponders for marking particular obstacles are straightforward and could be used in conjunction with Advanced Marine Radar and scanning sonars respectively. The number and type of these will not be known until extensive topographic and and hydrographic mapping of routes is done. LORAN C could be utilized for primary navigation.

8.3.2.1 LORAN C

Complete coverage of the Northwest Passage and Arctic Islands with a LORAN C (or equivalent) navigation chain is not considered necessary. It is recommended for use in narrow channels or chronically difficult



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: NAVSS BLOCK DIAGRAM (SHIPBOARD)
		FIGURE No. 16

ice infested regions. Specifically LORAN C is recommended because it is well known and trusted throughout the world. Moreover, although LORAN C accuracy degrades with range and geometry (as do all hyperbolic ranging systems), intermittent, non-overlapping regions (umbrellas) of LORAN C coverage can provide adequate coverage for absolute georeferencing. Positioning accuracies will be best within the coverage of the umbrellas and will degrade between umbrellas at a rate consistent with the dead-reckoning capability of the vessel.

To evaluate this concept, it is worthwhile considering a typical LORAN C chain which has been proposed to provide coverage in the Beaufort Sea Region. The network would be administered in the same manner as those chains on the East and West Coasts of Canada to provide the following capabilities:

(i) Survey accuracy coverage suitable for all aspects of oil exploration and development including seismic positioning, rig or drillship movement, pipeline surveys and pipe lay control.

(ii) Precise positioning services for general shipping, supply vessels, dredges, etc.

(iii) Helicopter and fixed wing aircraft navigation and the facility for air traffic control.

iv) With the proper shore station configuration provide navigation for land seismic vehicles.

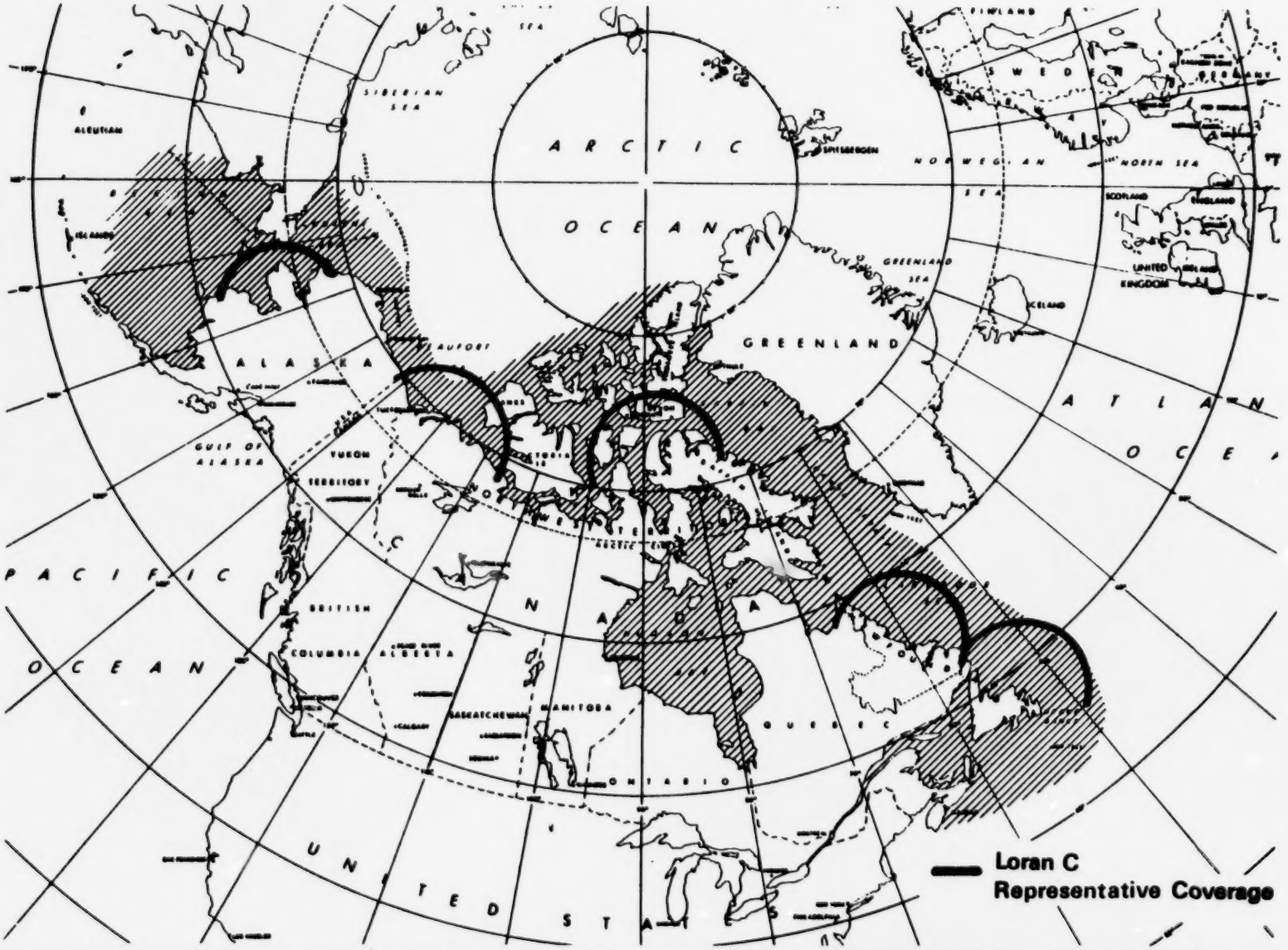
v) The facilities to track remote objects such as icebergs.

vi) The system works on a 24 hour basis, is unambiguous and normally operates at ranges up to 500 nautical miles.

Individual LORAN C chains would be installed throughout the areas of interest to provide this non-continuous coverage (see Figure 17). Vessels would dead reckon between areas of coverage using INS or, a more recent development, an integrated LORAN C/TRANSIT SATNAV receiver which utilizes LORAN harmonics at much greater ranges to continuously update the satellite position fixes. This system, known as LORSAT, will be tested in the Beaufort in the fall of 1984.

8.3.3 REMSCAN Central Facilities

As stated earlier, the NAVSS design concept relies heavily on shipboard sensor interpretation and display. However, for those vessels not equipped with such systems and, in particular, for those vessels which rely on REMSCAN to provide tactical, as well as strategic, ice information and route selection, a central version of NAVSS will be located at REMSCAN Central. This system would perform the same functions as the shipboard version, but larger in scope, depending on the number of ships supported. The NAVSS



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN LORAN COVERAGE
		FIGURE No. 17

consoles would be similar and the relationship to the central RSS components would be identical to the shipboard version. The difference would be that the sensor inputs would be remotely acquired (as with the RSS) and essential navigation parameters would be sent to the central NAVSS in time for real-time processing. The central NAVSS processor must be large enough to handle the increased processing load (many vessels versus one) and the console would (obviously) not be integrated with marine radars. The NAVSS display would likely be integrated with the RSS console to facilitate the geocoding process of imagery and ice charts. A block diagram of the REMSCAN Central NAVSS is shown in Figure 18.

8.3.4 Cost Estimates

8.3.4.1 Shipboard

(assuming vessel already equipped in accordance with federal regulations)

NAVSS Console	55K
NAVSS Central Processor	75K
	130K

8.3.4.2 REMSCAN Central

NAVSS Console	55K
NAVSS Central Processor	1,000K
	1,055K

8.3.4.3 LORAN C Chain

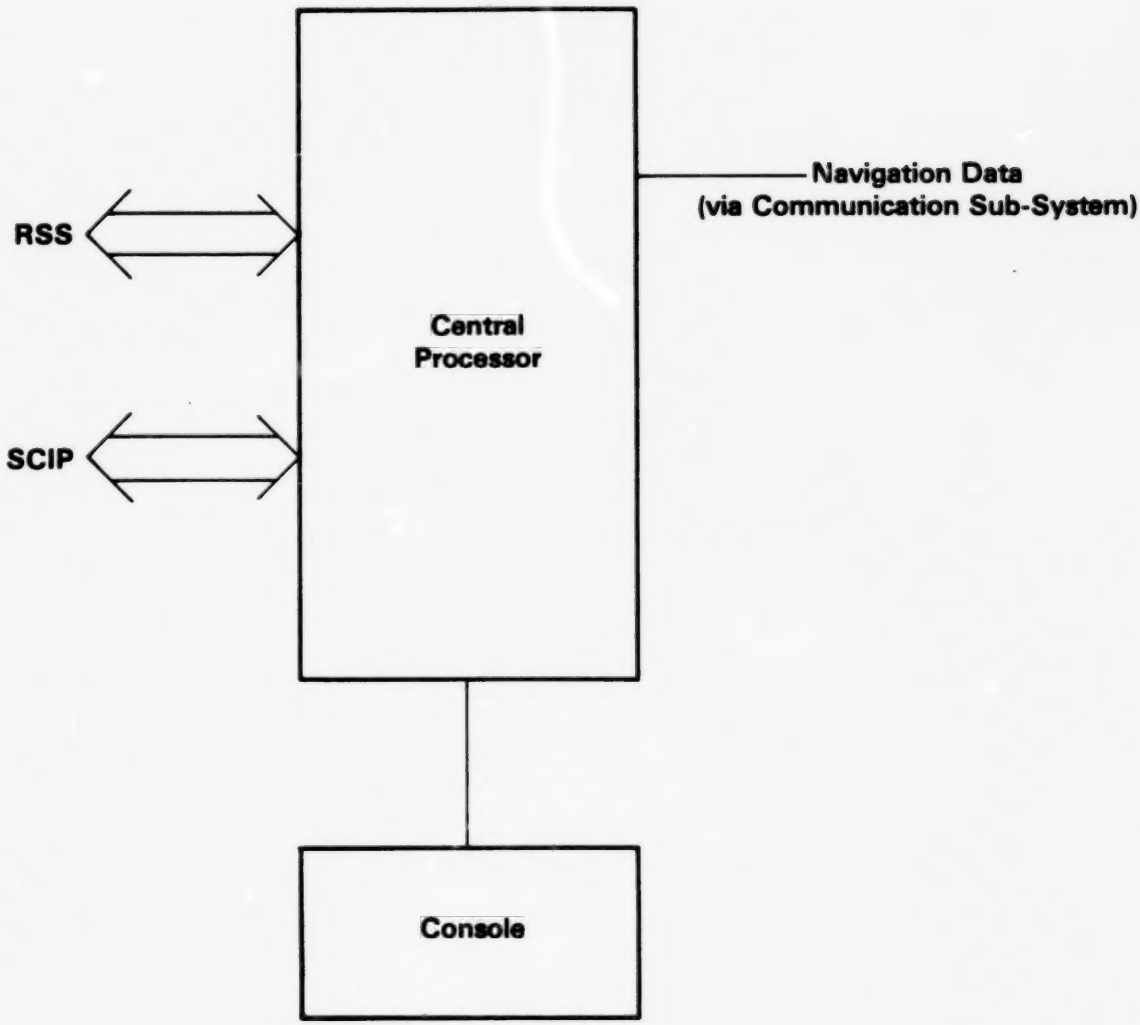
(three required)	
3 chains providing equivalent of Beaufort Sea coverage	3 x 5,000 K
	15,000K

8.3.4.4 Development Costs

Prototype	
Shipboard	250K
Central	2,500K
LORAN C (study only)	250K
	3,000K

8.3.4.5 Operating Costs

Personnel (same personnel as for RSS)	0
Operating/Maintenance (LORAN C)	2,000/yr.



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: NAVSS BLOCK DIAGRAM (REMSCAN CENTRAL)
		FIGURE No. 18

8.4 Communications Subsystem Design

8.4.1 Network Layout

Figure 19 indicates the principal information types transferred between remote segments of the REMSCAN network. The Regional Centres, located either at or near users' production sites or at federal agency sites, will communicate with vessels using MF/HF/VHF radio or MSAT as dictated by range requirements. Such links may be provided by the common carriers via a radio telephone type service but more typically would be provided by the user on the ship end and REMSCAN on the shore side.

The existing arctic Coast Guard radio stations are logical locations for REMSCAN Regional Centres. Specifically, the CCG stations at Inuvik (or Tuktoyaktuk), Resolute Bay, Frobisher Bay and St. John's are well situated for REMSCAN applications and are amongst the best equipped of the Arctic and North Atlantic stations.

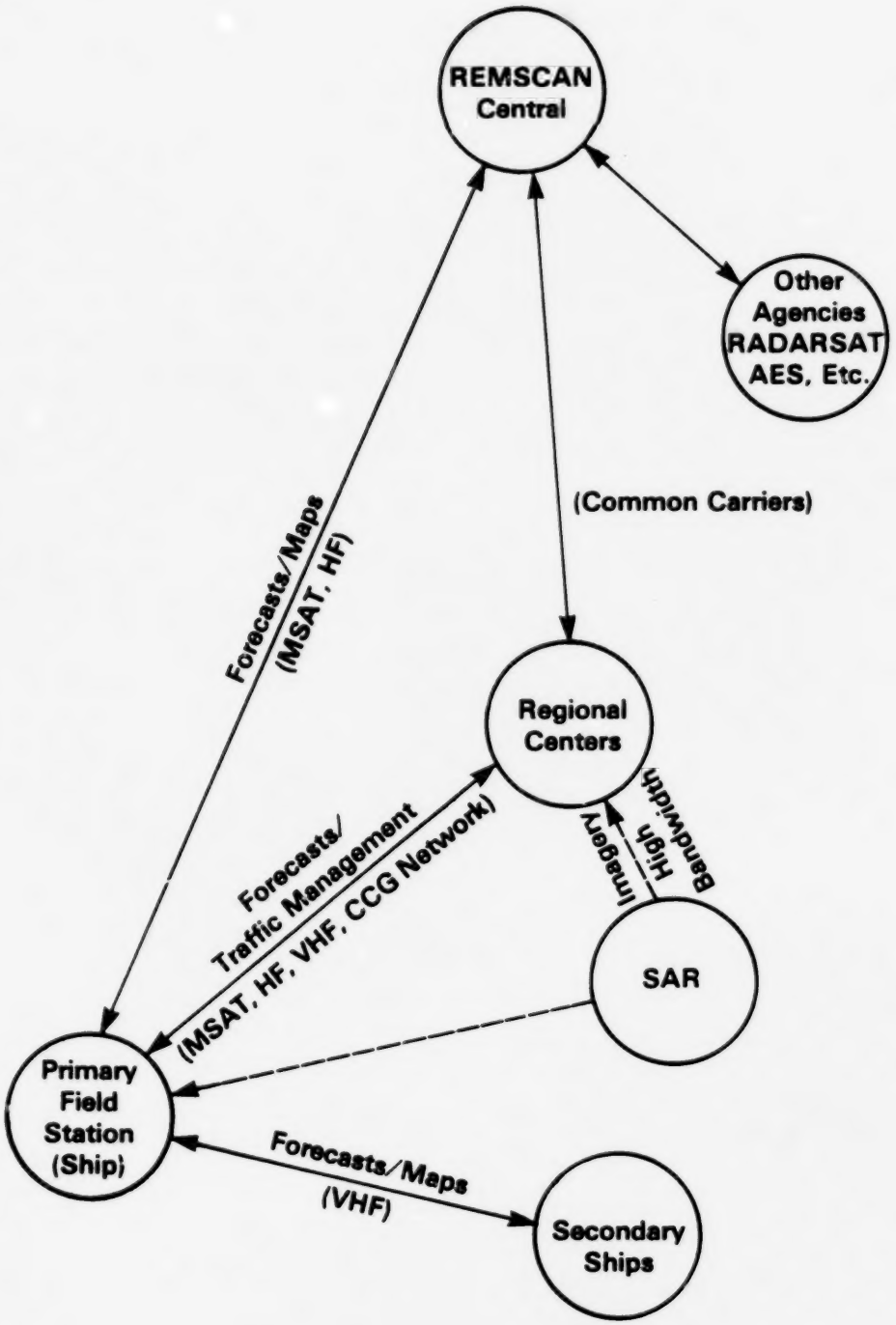
Information from other agencies such as NOAA and LANDSAT will enter the network at REMSCAN Headquarters for integration with other data bases. Maps and forecasts will be distributed from REMSCAN Central in a broadcast mode to subscribers using MSAT or HF radio. The major advantage of broadcasting is that many users will be updated simultaneously, thereby reducing transmission time.

To a large extent, vessels will operate in a stand alone manner, thus minimizing the requirement for highly reliable, full period communications with other sites. In order to achieve this level of autonomy, a high degree of local processing ability will be situated on the vessel with appropriate intra-ship communications linking the processing system components.

8.4.2 The ISO Open Systems Interconnection Reference Model

The International Standards Organization (ISO) has developed a model for Open Systems Interconnection (OSI). It describes the framework for a seven layer data network architecture with each layer performing distinct communications functions. By the mid 1980's standards describing each layer will be fully developed.

"Open" in this context refers to data networks which are capable of exchanging information with other open networks. Hence the OSI model pertains to the requirements for external communication between open networks with each possibly having different architectures. OSI does not describe the system's internal communications architecture. That role is fulfilled by specific network architectures such as IBM's SNA, Digital Equipment's DECNET or a local area network architecture. Table 7 summarizes the application of open networks to REMSCAN. The most important reasons for applying the OSI model to the REMSCAN system are:



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: REMSCAN INFORMATION TRANSFER
		FIGURE No. 19

TABLE 7

THE ISO NETWORK MODEL APPLIED TO REMSCAN

LAYER	FUNCTION	REMSCAN APPLICATION	INFORMATION UNIT
7. Application	Allows user programs on dissimilar machines to interact. Partition computing load amongst various machines.	Allows REMSCAN users owning different computers to exchange information. Allocates computationally intensive tasks to dedicated devices such as image processing equipment.	Message or Picture
6. Presentation	- Data Compression - Character Code Conversion - Encryption (if required)	Compresses SAR imagery or text prior to transmission on narrow bandwidth channel.	Message or Picture
5. Session	Logon/Logoff Sequence	- Authenticates a users access privileges (via password) - establishes a users connection to the REMSCAN network - ensures that the correct party is billed	Message
4. Transport	Provides end to end error control and packet multiplexing.	Ensures essentially error free data transmission between the REMSCAN source and destination.	Message
3. Network	Determines routing of data packets.	Selects which communicationmedia(s) (MSAT, Land Line, etc.) to transmit the data over.	Packet
2. Data Link	Checks for and corrects data communication errors between adjacent nodes.	Ensures that each data link within the REMSCAN network operates error free.	Frame
1. Physical	Mechanical and electrical interface between communications devices ie: RS-232.	The majority of REMSCAN equipment will be connected by this interface.	Bit

- Most new data communications products are designed to perform functions of one or more OSI layers. For example all data modems conform to the layer one model (the physical layer) while many intelligent multiplexers employ ISO's X.25 protocol which meets the error correction objectives of layer 2 (the Data Link layer).

- Many public data networks such as Telecom Canada's Datapac network agree to some extent with the OSI model.

- A layered architecture allows for simple segmentation of design tasks, maintenance functions, etc.

- The complexity of the interface between layers is minimized, further simplifying system design.

8.4.3 Communications Subsystem Components

The network consists of subsections, each performing one segment of the overall communications function. The principal subsections are Local Area Networks, Long Haul Networks, and Gateways. The subsections operate independently except where they must interface with each other. Hence the failure of one segment does not unduly effect the operation of the others. In the following sections only those communications specifically required for REMSCAN are described. Other communications such as VHF marine radio and office telephone systems are assumed to be in place.

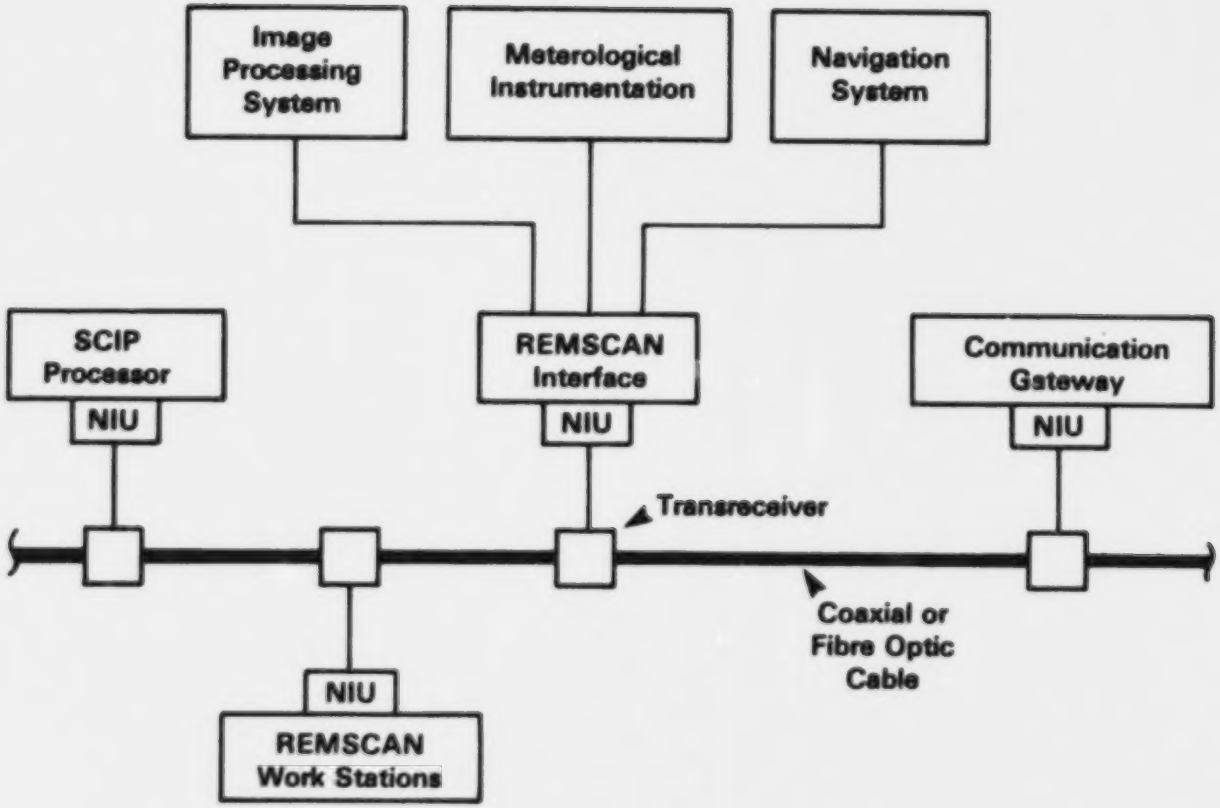
Appendix C includes manufacturer's literature on the following:

- Ungermann-Bass "Net/One" network system
- Glenayre Electronics. HF mini-terminal
- Glenayre Electronics. HF pulse compression modem
- SR Systems packet network access system

8.4.3.1 Shipboard Communications - The Local Area Network

The geographically distinct areas of REMSCAN, such as vessels, Regional Centres and REMSCAN HQ will each operate with its own LAN. The LAN provides short range packet switched communications between terminals and other peripherals, data processing equipment, and external communication gateways. Figure 20 shows a LAN as would typically be found on a fully equipped REMSCAN vessel. Data is distributed at high speed usually over coaxial cable although fibre optic cable may find application in high electromagnetic interference environments as found on ships. Network Interface Units (NIUs) allow for attachment of dissimilar devices to the LAN.

Digital telephone exchanges (PABXs) are an alternative to LANS and offer the advantage of integrated voice/data switching over the same cable. However digital transmission is presently limited to 56 KBS and the feature is usually only found in larger capacity PABXs. Although 56 KBS appears to be relatively fast, it is too slow to be useful for shared memory applications amongst peripherals such as disk-disk file transfer. The principal characteristics of local area networks are:



NIU - Network Interface Unit

CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: LOCAL AREA NETWORK SHOWING ATTACHMENT OF REMSCAN SUBSYSTEMS FIGURE No. 20

- Most new data communications products are designed to perform functions of one or more OSI layers. For example all data modems conform to the layer one model (the physical layer) while many intelligent multiplexers employ ISO's X.25 protocol which meets the error correction objectives of layer 2 (the Data Link layer).

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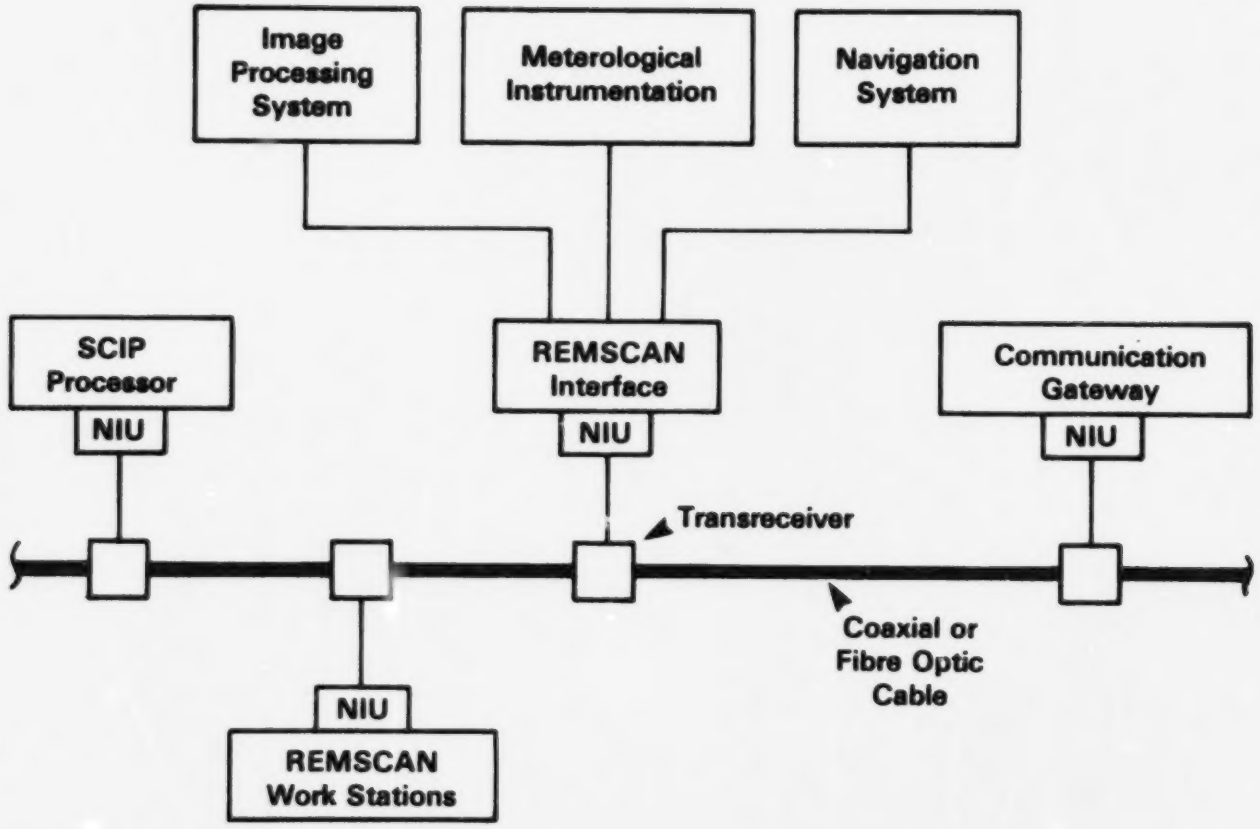


NIU - Network Interface Unit

CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: LOCAL AREA NETWORK SHOWING ATTACHMENT OF REMSCAN SUBSYSTEMS FIGURE No. 20

- High data rates within the local area (0.1 to 10 MBS typically).
- Consistently low error rates.
- The network is owned by a single organization.
- The network extends for at most a few miles and is usually confined to one building (or ship).

The LANS at different locations need not be from the same manufacturer or even compatible amongst one another, since gateways will be used where intercommunication is necessary as illustrated in Figure 21. Ethernet, supported by many competing vendors such as DEC, Xerox HP, and Intel is currently the most popular LAN architecture.

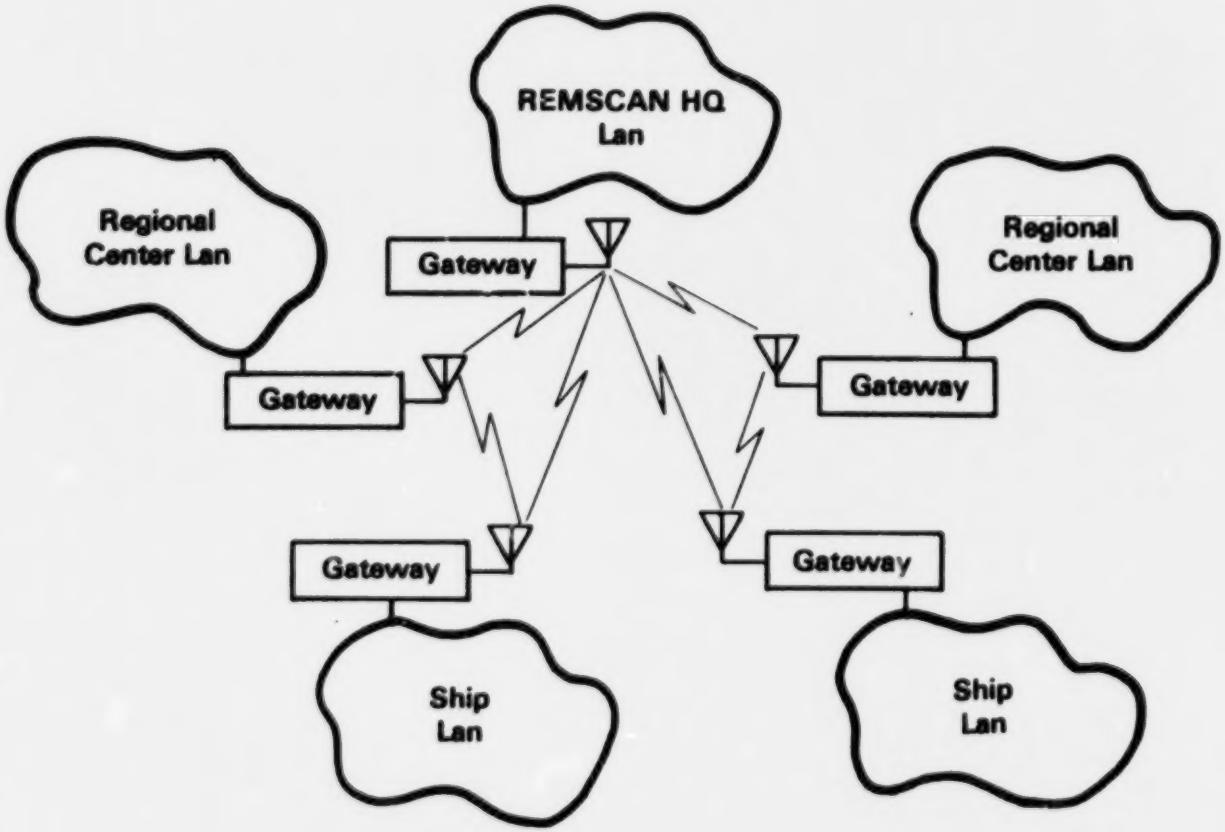
A star or bus topology is recommended as it generally has higher throughput than other structures due to lower transit times resulting from shorter cable lengths between extreme locations. Addition of nodes to the network and maintenance activities are also easier with a star configuration since the other branches are not disrupted.

LANS are not used in tightly coupled systems such as between a processor and auxiliary memory or a data acquisition system. Instead the processor's data bus will be extended to the auxiliary device, enabling much higher data transfer rates. It is not important to REMSCAN what bus standard, if any, is used as the choice will not significantly affect overall REMSCAN operations. However it is to the user's advantage to select one of the so called "standard" buses in order to broaden the supply base of equipment and minimize the effects of product changes by a sole manufacturer.

8.4.3.2 Long Range Communications - MSAT and HF Radio

MSAT will be the principal long haul network for REMSCAN voice, data, text and facsimile communication requirements. Vessels will be equipped with MSAT UHF mobile radio terminals for communication with other vessels, Regional Centres, REMSCAN Headquarters and public voice and data networks. Fixed applications such as production platforms and Regional Centres will use a mix of UHF and SHF base stations as determined by coverage, traffic and link performance requirements. REMSCAN Central will use one or more multichannel SHF base stations in order to efficiently serve a large number of subscribers. All MSAT terminals used for REMSCAN applications will be equipped with the TX/RX data option allowing direct connection of data communication devices.

Amongst the expected MSAT services, an important trade-off occurs between UHF and SHF band base stations. SHF base stations will provide full Canada coverage over a single satellite hop whereas UHF mobiles and base stations will require double hop communications. The advantages of single hop coverage are faster turn around time for half duplex communications and possibly lower usage charges, depending upon Telesat's rating structure. However SHF terminals at $70,000 (single channel), are much more expensive than their $7,000 UHF counterpart.



CANADIAN MARINE DRILLING LIMITED	REMSCAN FEASIBILITY STUDY FINAL REPORT	TITLE: COMMUNICATION BETWEEN LOCAL AREA NETWORKS USING GATEWAYS
		FIGURE No. 21

Basic bit error rate (BER) performance over MSAT channels will be poor, typically 10^{-2} to 10^{-3}. Forward error correction (FEC) techniques will be employed to improve BER performance to the 10^{-5} to 10^{-6} range. The penalty incurred for obtaining lower error rates by FEC is a greater number of overhead bits transmitted and hence a longer transmission time.

A very useful feature of MSAT will be its ability to broadcast to a predetermined group of terminals. This will be used by REMSCAN Headquarters to simultaneously transmit maps or forecasts to a select group of REMSCAN subscribers, who for instance only require information for the Beaufort Sea area. Selective broadcasting is achieved in the MSAT design by building a unique address into each terminal. Selective addressing could prove useful for restricting REMSCAN service to paying customers.

Shortwave (MF/HF band) radio has traditionally been used for Arctic voice communications. HF will continue to be required after implementation of REMSCAN, primarily as backup for MSAT and for servicing non MSAT equipped ships. A long range HF station would be constructed near REMSCAN Headquarters in a rural, electrically quiet area. HF channel quality and reliability can be improved considerably by using add-on equipment such as Marconi's RACE automatic frequency hopping system. However, RACE equipment would be required on both ends of the HF link, which may be impractical to implement on smaller vessels because of its high cost ($18,000).

8.4.3.3 Short Range Communications - Air/Ground and Ship/Ship Links

High speed digital radio downlinks will be used extensively for real time shipboard reception of SAR/SLAR imagery from aircraft. Data rates approaching 1.5 MBS may be required. Although air/ground links are not part of REMSCAN per se, they are mentioned here because of their critical importance in distributing SAR information.

Ships presently utilizing downlinks are only equipped with receivers. However, by installating a compatible transmitter, stored imagery can be shared amongst vessels as they pass within line of sight. A time window of approximately two hours would be available for exchanging data between ships travelling in opposite directions.

Ship-ship data links will also be used by vessels travelling in a convoy, principally for distribution of information from the escort vessel to client ships.

Obviously compatibility amongst these links will have to be established in order to take full advantage of data sharing.

The radio downlink equipment need not be spectrally efficient owing to its short range and exclusive use in remote areas. This will result in cost savings when compared to equivalent radio equipment designed for use in congested urban areas. However the Department of Communications has the ultimate authority to permit use of such equipment. The DOC will likely restrict operation of these links to the 2.3 to 2.9 GHz

telemetry band. Miller Communications Ltd. have been designing and building SAR/SLAR downlinks for a number of years.

8.4.3.4 Gateways

Gateways convert data from one protocol to another thereby preserving the existing network architectures. They are shared by all devices within the local network that require external access. The sharing ability differentiates them from protocol conversion devices which only support a single peripheral. Typical gateways available today will interface X.25 packet switched networks such as Datapac with most other network architectures including SNA, DECNET and the more common LAN protocols. Several gateways are illustrated in Figure 12.

Information products destined for transmission to other REMSCAN locations will first be transferred to buffer space in the appropriate gateway. The data will then be formed into packets, a communication media selected, and the data forwarded to the corresponding gateway where the reverse process occurs.

Gateways can only translate between protocols that perform similar functions. i.e. Both protocols must be capable of providing the information expected by the other.

8.4.4 Communications Subsystem Costs

The costs below are for communications equipment and services required as a result of REMSCAN. Costs for other communications systems such as telephones, marine radio, etc are not given as they are already in place regardless of REMSCAN presence.

Shipboard	Cost $k
MSAT terminal	$ 6
Local Area Network	25
2 workstations, 1 printer	4
REMSCAN Interface (Hardware)	10
Gateway	6
HF Modem	10
Misc. Modems, Cabling, cabinets	5
Power Supply and Conditioning	5
Installation and Commissioning	20
	$91

Regional Centre	
MSAT UHF Base Station	7
Local Area Network	25
3 Workstations, 2 Printers	10
REMSCAN Interface	10
Gateway	6
HF Modem	7
Power Supply and Conditioning	10
Miscellaneous Modems and Cabling	7
Installation and Commissioning	12
	$94

REMSCAN Central	
MSAT SHF Base Station (5 Channels)	95
Local Area Network	35
6 Workstations, 2 Printers	15
REMSCAN Interface	10
Gateway	6
HF Modem	7
Power Supply and Conditioning	50
Miscellaneous Modems and Cabling	10
Long Range HF Station	90
Installation & Commissioning	30
	$348
Development Costs	
Communications Software (Gateway and Interface)	$150
Operating and Useage Costs (per year)	
MSAT	50
Datapac	5
Leased Lines	10
Equipment Maintenance	40
HF Site Land Lease	3
	$108 /Yr

8.5 System Control and Information Processing Subsystem

Estimates of magnitude of software size and complexity and of the corresponding hardware required are based primarily on the experience of Dome Petroleum with a Winter Ice model used to predict ice conditions in part of the Beaufort Sea. Resource use of this model has been extrapolated for a model of the size anticipated for REMSCAN.

The following paragraphs list the software and hardware required for the SCIP functions of REMSCAN. A summary appears in Table 8.

8.5.1 Vessel Software

A fully participating vessel - that is, one capable of receiving and interpreting SAR scans, and of exchanging Reduced Ice Maps (RIM's, resolution 200 m) with a Regional Centre - will need the following software:

RIM Storage	A 'Tiling' system to insert received data into the local database (see Section 7.9.1, Assembly).
RIM Comparison	A system to compare and contract related RIM's for validation and trend extraction (see Section 7.9.2, Evaluation).

TABLE 8

TABLE 8: SIZE ESTIMATES OF SCIP COMPONENTS

	DEVELOPMENT EFFORT	OPERATIONAL COST	FUTURE GROWTH POTENTIAL	STORAGE REQUIREMENT	CPU REQQUIREMENT	PERIPHERALS
VESSEL, REGIONAL CENTRE, AND CENTRAL FACILITY SOFTWARE:						
RIM Storage	small	v. small	not likely	SEE TEXT	small	Hard disk or equivalent
RIM Comparison	small	v. small	moderate	small	small	Hi-res display
RIM Retrieval	small	v. small	moderate	small	small	Color plotter
RIM Communications	moderate	moderate	moderate	small	small	2400 baud link
REGIONAL CENTRE ONLY:						
Dissemination (to vessels)	moderate	moderate	moderate	small	small	SEE TEXT
Control Functions	large	moderate	large	small	moderate	None
Hazard Check	small	small	moderate	small	small	None
Archiving (activities)	small	small	small	moderate	small	Hard disk or equivalent
Summer Ice Model (optional)	moderate	moderate	moderate	moderate	large	Dedicated CPU
CENTRAL FACILITY ONLY:						
Integration	moderate	moderate	large	moderate	large	
Forecasting						
- Ice Map (Winter Model)	v. large	large	large	v. large	v. large	Array processor
- Route Optimization	large	v. large	large	v. large	v. large	Array processor
- Oil Spill	large	large	large	moderate	v. large	Array processor
Dissemination (to regions)	small	small	moderate	small	small	Dedicated links
Archiving (entire system)	small	large	moderate	huge	small	Optical disks?
Control Functions	large	moderate	large	small	moderate	

APPROXIMATE SIZES:	man-months	Mbytes	MIPS
small	2 to 6	0 to 5	0 to 0.1
moderate	7 to 23	5 to 100	0.1 to 0.5
large	24 to 100	100 to 500	0.5 to 5
v. large	100 & over	500 & over	5 & over

RIM Retrieval	A system to recall and display RIM's on screen or hard copy, for tactical and strategic decision making.
RIM Communications	For up- and down-loading of RIM's (see Section 7.9.5, Dissemination).

None of these models is expected to be large or complex. A summer ice model would be both, however, in terms of on-board capability (see Section 8.5.4, Vessel Hardware).

8.5.2 Regional Centre Software

Regional Centres will require all of the above modules. They will also need additional communications capability to deal with less-than-fully-participating vessels (facsmile, teletype, voice), and some control function software (see section 7.9.7).

It is not likely to be cost effective to prepare forecasts at the regional centres, since the forecasting model must consider as large an area as possible to produce reliable output (ice maps), and hence will be most effective at the central facility.

A simple model to detect the presence of ice conditions hazardous to vessels within a day's cruising range of each might serve as a useful backup to manual examination of ice maps, while presenting only minor computation demands.

A summer ice model (see definition in Subsection 7.9) could be operated at the Regional Centres, but would represent a significant increase in computational load.

Some archiving of activity logs will be required, and if any forecasts of any kind are produced at a Regional Centre, these too should be archived. If data from the RSS not sent to the central facility (eg. SAR data at finer than 200 m resolution) are to be kept, at least an index to this data should be included in the SCIP archives.

8.5.3 REMSCAN Central Software

The central facility will require all of the capabilities of a Regional Centre, plus programs to integrate data from disparate sources (see Section 7.9.3), forecasting modules (see Section 7.9.4) and a more extensive archiving system (see Section 7.9.6). The forecasting programs especially will be very large and complex.

8.5.4 Vessel Hardware

Full participating vessels will need at least one high resolution screen with color capability, and a color hard-copy plotting device. Also, a 2400 baud data communications link will be required for image and data exchange with the nearest regional centre. Computational and storage requirements are small relative to the RSS, so if the workstation chosen for that purpose was of sufficiently general-purpose

design, it could handle the small SCIP workload in addition to its normal function. At most, a special purpose SCIP interface board would need to be added to the workstation to perform data formatting and communications functions.

If it was desired to implement a summer ice prediction model on board vessels, a relatively large stand-alone system would be required. Such a system has not been included in the estimates.

8.5.5 Regional Centre Hardware

A Regional Centre will need at least one high-resolution color screen and color plotter, and backups for each. More may be required if the volume of traffic is significantly higher than the scenarios studies for this document. Several 2400 baud links must be available for communicating with vessels, and two or more voice channels will be required. In addition, a facsimile transmitter (and receiver, to monitor the transmissions) and a teletype station will be required, and should have backups.

As with vessels, the computational requirements will be small and can be performed by the SAR interpretation workstations with at most an additional interface board in each.

Regional ice maps are expected to require about 25 Mbytes of storage each. Capacity for at least four at any point in time must be available, since it much be possible to load a new now cast and forecast before deleting the old ones. Thus, at least 100 Mbytes of fast-access (hard disk or equivalent) storage will be needed.

If the control function and/or hazard check software grow large, or if a summer ice model is implemented at the regional level, additional computing resources may be required. This has not been included in the estimates.

8.5.6 Central Facility Hardware

The central facility will need all the equipment of a Regional Centre (with the possible exception of 2400 baud data links) plus substantial computing and storage capacity. Since four forecasts must be prepared each day (two each of 12 hours and 24 hours ahead), the estimates for hardware are based on the assumption that the model must execute in 5 hours or less.

The computational demands of the integration and particularly of the forecasting program can be enlarged to consume virtually any hardware capacity. The estimates presented here represent the author's opinion as to the minimum capacity required to give confidence that the models will produce useful results.

Each complete ice map will occupy approximately 200 Mbytes, and the central database will need space for at least four copies at any one time, plus reserve capacity, leading to a requirement for 10000 to 1500 Mbytes of rapid-access storage (hard disk or equivalent). It is

possible that in practice the ice maps will be drastically smaller; perhaps as little as 10% of the core area (6 million km^2) will be at the maximum resolution of 200 m, and none of the surrounding area. If the remainder is available with a resolution of 1 km or coarser, the total storage requirement for each map may be less than 50 Mbytes. However, this has not been assumed for the purpose of estimating hardware capacity and cost. For archiving, the reduction could be even greater since the map for each stored nowcast and forecast might need to include only the core area.

8.5.7 Costs

The development of a special-purpose SCIP firmware module to be added to the SAR interpretation workstations is expected to cost $500,000. Once developed, each such module is expected to cost $5,000 to $10,000 to build. No other hardware cost is anticipated for vessels and regional centres in connection with SCIP functions, as the workstations have all the necessary peripherals.

The central facility requires a large mainframe CPU and substantial disk storage. An IBM 3081-K would provide minimal computing capability, and would require five 3380 disk drives with four controllers to provide the necessary storage capacity and performance. The disk drives should be duplicated for reliability. In addition, the system would require four tape drives for back-up, a 3705 communications interface, and various peripherals (console, printer, terminals, etc.). This system hardware would cost in the region of $3.5 million with an estimated annual operating/maintenance cost of $350 K. Software development costs are estimated to be in the range $2.5 - $5.0 million.

A similar system configured around an Amdahl VP1200 CPU would cost approximately 25% more, but would provide substantially greater processing power for compute-bound applications such as REMSCAN's forecasting models.

8.5.8 Summary of Costs

In this Subsection, capital costs are summarized for:

- A representative major vessel
- A Regional Centre
- REMSCAN Central

Operating/maintenance costs and development costs are also estimated.

8.5.8.1 Major Vessel Capital Costs

a)	Remote Sensing Subsystem	$120 K
b)	Navigation Subsystem	130 K
c)	Communications Subsystem	91 K
d)	System Control and Information Processing Subsystem	10 K
e)	Interface Hardware	15 K
	TOTAL	$366 K

8.5.8.2 Regional Centre Costs

a)	Remote Sensing Subsystem	$120 K
b)	Navigation Subsystem	130 K
c)	Communications Subsystem	94 K
d)	System Control and Information Processing Subsystem	10 K
e)	Interface Hardware	15 K
	TOTAL	$369 K

8.5.8.3 REMSCAN Centre Costs

a)	Remote Sensing Subsystem	$1,415 K
b)	Navigation Subsystem	16,055 K*
c)	Communications Subsystem	348 K
d)	System Control and Information Processing Subsystem	3,500 K
e)	Interface Hardware	15 K
	TOTAL	$21,333 K

* Includes $15,000 K LORAN-C Chain.

8.5.8.4 Operating/Maintenance Costs

Shipboard operating costs are essentially nil since personnel must be available in any case for shipboard functions, and REMSCAN will impose only a small, incremented work loads. The major component of operating and maintenance cost is associated with the REMSCAN Central Facility.

a)	Remote Sensing Subsystem	$3,750 K
b)	Navigation Subsystem	2,000 K*
c)	Communications Subsystem	108 K
d)	System Control and Information Processing Subsystem	350 K
	TOTAL	$6,208 K

8.5.8.5 Development Costs

The integrated development cost for the baseline REMSCAN system over and above hardware and software capital costs, is estimated at:

a)	Remote Sensing Subsystem	$6,000 K
b)	Navigation Subsystem	3,000 K*
c)	Communications Subsystem	150 K
d)	System Control and Information Processing Subsystem	5,000 K
	TOTAL	$14,150 K

8.6 REMSCAN Interface Design

The input and output interfaces demarcate the functional boundaries of REMSCAN. In may instances the interface will be a simple electrical connection between REMSCAN and non-REMSCAN devices as would be found on a ship. However, the interfaces are not only electrical in nature but also include activities such as co-ordination between REMSCAN users and other agencies, NORDREG for instance.

The REMSCAN interface will usually connect systems within close proximity and therefore a standard physical data communications interface such as RS-232 or V.24 is adequate. Actual information exchanges will occur by way of a high level protocol such as X.25. Protocol incompatibility will be resolved through use of gateways or protocol converters.

The SCIP subsystem will oversee REMSCAN interface tasks. The interface software will reside in the SCIP processors except for dedicated, software driven devices such as protocol converters.

8.6.1 Costs

REMSCAN Interface costs are largely included in the SCIP software costs. Dedicated hardware devices such as X.25 packet Assemblers/Disassemblers and protocol converters will cost approximately $10 - 15 K per REMSCAN location.

8.7 REMSCAN Organization and Management

A REMSCAN infrastructure composed of a management team, and personnel resources would be required, the functions of which would be as follows:

- Provide framework for REMSCAN housekeeping (technical, organizational, and financial)
- Allocate and manage system resources
- Direct priorities for data collection, processing and output products
- Liaise with external agencies and facilities
- Liaise with users
- Regulate and coordinate participation by users
- Provide manual and automated (as required) facilities for subsystems, in particular, REMSCAN interfaces and information processing
- Operate and maintain special-purpose REMSCAN facilities
- Manage functional and technical evolution of system

Some of these functions might be automated and included within the context of the SCIP subsystem.

8.7.1 Fiscal Implications

The fiscal administration of REMSCAN would of course be a responsibility of the REMSCAN infrastructure. The system concept as set forth has some immediately apparent implications in this area and in overall financing as well. These are set out in this Subsection.

a) The capital cost of the system to the managing organization would be low due to:
   - Reliance being placed on users for front end sensing equipment including SAR flights and display facilities wherever possible

- Leasing of common carrier communications channels wherever possible
- Heavy dependence upon existing systems and capabilities (such as Ice Central) in baseline system. Incremental upgrading costs would account for much of the overall capital expenditures.

Capital costs to users would be variable depending upon their levels of participation and upon the degree of regulation imposed upon them.

b) Operating costs to the managing organization in respect of equipment would also be minimal due to the above considerations. Administrative costs would be dependent upon the size of the regulatory machinery necessary to maintain operating standards and ensure compliance with applicable statutes.

c) Direct cost recovery of system overhead would be possible on the basis of:
   - Fees for service
   - Licensing of users
   - Cost sharing with other organizations (AES, etc.)

9.0 IMPLEMENTATION

The system described in the proceding parts of this report was designed in detail sufficient to demonstrate the technical feasibility of the REMSCAN concept and to permit rough costing to the subsystem level. The system was not optimized in any sense and was moreover configured to suit a particular, hypothetical, although plausible operational scenario.

Actual implementation of REMSCAN should therefore take into account.

- Deviation of the developing operational scenario from the one assumed.

- The necessity for optimizating performance and cost.

This part describes the proposed phases of the implementation process.

9.1 System Definition Phase

The objective of this phase is to generate a complete design specification for an optimized REMSCAN system. This work must be proceded by:

- More detailed assessment of the operational scenario to be supported.

- Establishment of regulatory requirements concerning operational ice information.

- Establishment of agreements in principle covering the kind and level of participation in REMSCAN by various government and industrial organizations.

9.1.1 Scope of Work

The following broad tasks would be necessary:

- Review of system-level requirements/specifications.
- System conceptual design.
- System optimization.
- Preparation of complete design-level specifications.
- Estimation of costs/schedules for the remaining phase.

9.1.2 Level of Effort

The following level of engineering effort is foreseen as necessary to carry out the above tasks:

Subsystem	Man Months
Remote Sensing	12
Navigation	6
Communications	6
System Control and Information Processing	12
	36

9.2 Design and Development Phase

Design and development are often iterative processes which include, among other tasks, the fabrication of an engineering prototype. This approach is obviously not suited to a one-of-a-kind system of the magnitude of REMSCAN. A "testbed" development approach is therefore recommended in order to minimize development time and cost.

The term "testbed" here implies that, although the system will be used as a prototype for engineering test purposes, it will nevertheless be fabricated to operational standards. In this way, overall development time and cost will be minimized, although the cost of individual design modifications may be relatively costly.

9.2.1 Scope of Work

The design and development phase will comprise tasks as follows:

- Software design
- Network design
- Hardware, equipment, facilities design/procurement
- Software development
- Procurement/leasing of services
- Installation
- Non-operational testing (with modification as necessary)
- Operational testing (with modification as necessary)
- Commissioning

9.2.2 Level of Effort

The following level of engineering effort is foreseen as necessary to accomplish the above tasks:

Subsystem	Man Months
Remote Sensing	48
Navigation	24
Communications	24
System Control and Information Processing	60
	156

9.2.3 Other Costs

Costs of hardware, software, equipment, facilities, and service leasing costs are dependent on the particular system configuration adopted for the development phase and cannot be approximated without first determining the scope of the testbed developement phase. Estimates for development individual subsystems have been provided; however, no attempt has been made to estimate development costs associated with system integration. Furthermore, decisions to superimpose the REMSCAN infrastructure on existing resources of the AES and CCG are of a political nature, and must be addressed prior to defining an approach to system implementation. Definition of individual REMSCAN subsystems can; however, be achieved in advanced of, or concurrently with, the definition of the overall system integration plan.

10.0 RECOMMENDATIONS AND CONCLUSIONS

The main objective of this study was to investigate the feasibility of a coordinated, multi-user approach to the acquisition, processing, and dissemination of ice information found through experience to be useful and/or desirable in the conduct of safe, effective, offshore operations, including oilspill response operations.

A secondary objective was to investigate the utility of strategic information to vessels transiting ice infested waters, by means of a Vessel Transit Simulator.

Major conclusions and recommendations are summarized below.

(a) Based on 110 hours of trials using the simulator, a vessel transiting predominantly first year ice with multi-year inclusions and leads was able to achieve a 17% increase in speed when strategic (airborne radar) information was made available. The characteristics of the vessel exceeded Arctic Class 4.

(b) A system to provide needed ice information (with one major exception noted in (c) below) was found to be feasible on the basis of available and anticipated information processing, communications, navigation, and remote sensing technology. The system utilizes a mix of on-board and centralized facilities, and appears compatible with the approaches being pursued by both Canarctic Shipping and the Atmospheric Environment Service.

(c) The provision of near-real time ice information by REMSCAN to meet close-tactical needs is not recommended because of the extreme demands which it imposes on communications channel capacity.

(d) The exclusion of sensors and other data sources from the REMSCAN system is recommended in order to maximize vessel autonomy with respect to sensor choice, without incurring the high cost and complexity of maintaining system compatibility with data from a potentially large variety of sensor types.

(e) It is recommended that front-end (i.e., on-ship, on-site) pre-processing and pre-interpretation of raw data be carried out to yield a consistent REMSCAN input data format compatible with low bandwidth communications channels.

(f) It is recommended that tactical and strategic nowcasts and forecasts be prepared using interpretive and computing facilities situated at a central location.

(g) Normal use cannot support raw data transmission.

10.1 Development and Design Study Recommendations

REMSCAN is intended to deliver best available ice information, synthesized from all available data. Although the quality of REMSCAN output information is therefore not expected to be highly sensitive to isolated deficiencies in any specific function, there are several

noteworthy areas in which clear needs for improvement have been identified. These are listed below, for each of the four major REMSCAN functional areas, and also for the Vessel Transit Simulator.

10.1.1 Simulator

- Adaptation of existing simulator for use with other vessel classes
- Modification of simulator to handle additional operational modes such as backing up along track
- Use of the simulator to carry out comprehensive studies of modes of information utilization for various vessel classes and ice conditions.

10.1.2 Remote Sensing

- Development of SAR imagery processing to assist ice-type discrimination
- Evaluation of image compression methods to facilitate narrow band communications
- Evaluation of image archiving technology
- Feasibility study of automated image mosaicing
- Development of an airborne ice thickness sensor

10.1.3 Navigation

- Determination of usable location accuracy of satellite navigation systems in the North West Passage
- Comparative study of Inertial Navigation System accuracies at high latitudes
- Advanced marine radar system development
- Optimization of LORAN-C coverage for the North West Passage

10.1.4 Communications

- HF modem performance assessment for communication between Arctic and southern Canadian sites
- Protocol development for HF fading channel communications and for noisy satellite channels
- Application of Telidon technology to ice map distribution
- VHF/UHF propagation trials in the Beaufort and Baffin Bay / Labrador Sea regions to complement existing data in the Central Arctic
- Surveys of electromagnetic noise on offshore drilling platforms

- Feasibility Study of stabilized satellite antennas for icebreakers

10.1.5 Information Processing

- Development of structured (modular) ice forecasting software
- Evaluation of optical discs for archival map storage
- Development of an efficient route optimization algorithm

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Summary Report

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REMSCAN FEASIBILITY STUDY
SUMMARY REPORT

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Prepared for the
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17 Abstract

This report documents a feasibility study for a system providing timely sea ice information for operational support to users in Canadian and contiguous waters. The primary information source is airborne radar imagery, downlinked to sites equipped to receive it. A key concept is pre-processing and pre-interpretation of the imagery in the field (using locally available, complementary data) to permit significant information from many sites to be transmitted on low bandwidth channels to a central facility. There, all available information would be processed to form a comprehensive map data base of ice conditions, current and forecast. Packages of information selected for particular users would then be transmitted by radio message, facsimile, or special colour graphic modes, depending on the users' preferences. The advantages of the system include timeliness, synergism, flexibility, compatibility, and cost effectiveness. The study also included the development of a vessel transit simulator, which was used to demonstrate the strategic utility of ice information.

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17. Résumé

Ce rapport rend compte d'une étude de faisabilité concernant un système d'information sur les glaces flottantes, capable de fournir une information immédiatement utile aux navires et aux plates-formes de forage se trouvant dans les eaux canadiennes ou tout près. Ce système fait appel à un service de reconnaissance aérienne des glaces utilisant des radars dont les images sont transmises directement aux postes récepteurs équipés pour les recevoir. Un concept fondamental du système envisagé est la possibilité d'effectuer sur les lieux mêmes un traitement préliminaire et une première interprétation de l'information recueillie, à la lumière notamment des observations directes faites sur place. Cette information serait transmise par liaisons hertziennes sur bandes de fréquences étroites à un centre de coordination où l'ensemble de l'information reçue de plusieurs sources serait traité, constitué en base de données et restitué sous forme de carte synoptique montrant les conditions de glace, actuelles et prévues. Enfin, des blocs d'information correspondant aux besoins particuliers des utilisateurs leur seraient transmis sous forme de messages radio, de télécopie ou d'infographie, au choix. Les avantages escomptés d'un tel système sont l'instantanéité de l'information qu'il fournit, son action synergique, sa souplesse d'emploi, sa compatibilité et son économie. Le rapport fait état aussi de la mise au point d'un simulateur de navigation dans les glaces, utilisé pour montrer l'utilité pratique de l'information véhiculée par le système.

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FOREWORD

The REMSCAN study was undertaken by the Transportation Development Centre, Transport Canada, to investigate the feasibility of an integrated system approach to the provision of ice information in support of marine shipping and other offshore activities in ice infested coastal waters of North America. The term "REMSCAN" stands for REMote Sensing, Communications, And Navigation, the front-end technologies upon which the approach is based.

The economic basis for REMSCAN is the potential for large scale development of offshore and land-based resources in the Beaufort Sea, in the Arctic Islands, along the east coast, and for the increased levels of marine shipping associated with them.

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1. INTRODUCTION

A knowledge of the characteristics, whereabouts, and predicted movements of ice is essential to the conduct of safe and cost-effective activities offshore. Organizations presently so engaged individually expend considerable efforts to obtain needed information.

The REMSCAN study does not propose any "magic" technological solutions to the difficult problems and costly surveillance activities involved in generating ice information. Rather, it proposes a co-ordinated, multi-user approach focusing on systematized data acquisition, processing, and distribution, making use of whatever and all ice data that might be available. The objective is to provide at reasonable cost comprehensive ice information covering a range and time span not otherwise accessible to the individual user.

2. CONCLUSIONS

The main objective of this study was to investigate the feasibility of a coordinated, multi-user approach to the acquisition, processing, and dissemination of ice information found through experience to be useful and/or desirable in the conduct of safe, effective, offshore operations, including oilspill response operations.

A secondary objective was to investigate the utility of strategic information to vessels transiting ice infested waters, by means of a Vessel Transit Simulator.

Major conclusions are summarized below.

(a) Based on 110 hours of trials using the simulator, a vessel transiting predominantly first year ice with multi-year inclusions and leads was able to achieve a 17% increase in speed when strategic (airborne radar) information was made available. The characteristics of the vessel exceeded Arctic Class 4.

(b) A system to provide needed ice information (with one major exception noted in (c) below) was found to be feasible on the basis of available and anticipated information processing, communications, navigation, and remote sensing technology. The system utilizes a mix of on-board and centralized facilities, and appears compatible with the approaches being pursued by both Canarctic Shipping and the Atmospheric Environment Service.

(c) The provision of near-real time ice information by REMSCAN to meet close-tactical needs is not recommended because of the extreme demands which it imposes on communications channel capacity. Normal use cannot support raw data transmission.

(d) It is recommended that field locations have autonomy in their choice of sensors and that the latter not be specified, owned, or operated by the REMSCAN infrastructure. System compatibility with the potentially large variety of sensor types would be maintained using interface equipment at each location.

(e) It is recommended that front-end (i.e., on-ship, on-site) pre-processing and pre-interpretation of raw data be carried out to yield a consistent REMSCAN input data format compatible with low bandwidth communications channels.

(f) It is recommended that tactical and strategic nowcasts and forecasts be prepared using interpretive and computing facilities situated at a central location.

3. INFORMATION NEEDS

As the major Beaufort Sea offshore operator, Dome played a significant role in planning offshore ice information systems aimed at satisfying its own anticipated oil production and transportation needs. In order that this prior work (REMSCAN) might benefit the overall group of potential ice information users, it was necessary to re-define its scope in the light of the needs of the group at large.

Ice information needs were therefore updated through discussions with potential users, namely, representatives of the offshore oil and gas industry and government organizations, and through reference to prior studies.

The significant categories of offshore users are:

- vessels permitted to operate independently
- vessels requiring an escort
- offshore sites
- oilspill response activities

In each category, ice information needs can in general be met by nowcast and forecast ice descriptions at levels of coverage appropriate to the following time scales:

- strategic: periods greater than several days in advance
- tactical: periods of the order of a day
- close-tactical: within a few hours

However, the spatial extent of the coverage appropriate to each time scale will depend sensitively upon the user's location and operational activity, as well as upon the time of year; hence there is a need to "customize" the information to be delivered to each user.

It is also necessary to take into account the need to assemble such customized information into a "package" compatible with the communication and display technology at each user's disposal, i.e., in one (or more) of the following formats:

- high resolution imagery
- colour-coded maps
- monochrome charts
- alphanumeric message/text information

A special requirement exists for route optimization information in support of shipping. It is desirable that vessels be provided with the capability to select routes which are optimal in the sense that they minimize cost, transit time, or some other factor.

3.1 Simulator

A significant part of the study comprised the fabrication and use of a Vessel Transit Simulator to demonstrate the utility of information concerning ice lying beyond the range of shipboard sensors. The simulator comprised a computer-driven colour graphics terminal which displayed, in real or accelerated time, the motion of a ship across a colour-coded map representing an icescape. The icescape actually used corresponded to a portion of the North West Passage, and was derived from airborne radar ice imagery.

Vessel motion was controlled (power, rudder angle) by a qualified ship's master with icebreaking experience. Based on a relatively short trial comprising 110 hours of running time, the availability of strategic information in the form of (simulated) airborne radar imagery resulted in a 17% improvement in vessel average speed, compared with the speed attained using only short range surveillance.

4. REMSCAN CONCEPTUAL SYSTEM

4.1 Definition

REMSCAN is a functionally integrated set of

- planning methods
- data acquisition means
- communication channels
- information processing and analysis means
- management methods

for providing ice related information throughout Canadian coastal waters to serve the needs of vessels and fixed-site offshore activities.

4.2 Scope

It was found to be necessary to restrict the design scope of the REMSCAN system in order to

- accomodate user preferences and priorities
- live with fundamental technical constraints
- maximize co-operation with and utilization of other existing and planned systems and organizations

As a result of the downsizing in scope, certain assumptions evolved as follows:

a) Sensors will, under most circumstances, be owned, operated, and maintained by the users as part of their normal complement of navigational or hazard detection instrumentation, over which most users wish to maintain control. In some cases, where data essential for carrying out REMSCAN functions might not be available when and where required, REMSCAN might have to operate some of its own sensors (e.g. SAR) or, at least, direct the attention of privately operated sensors.

b) REMSCAN will not address close-tactical needs. The range of user needs and preferences is widest at this level, creating a need for great information diversity precisely where detail is most significant. This results in a major limitation being imposed by the availability at reasonable cost of communications channels with sufficient band width.

c) REMSCAN will provide "dynamic expansion" of on-board ice sensing capability as required. The availability of REMSCAN on suitably equipped vessels could be for example, equivalent to having "smart" radar with extra range switches and interpretive capability, or to having a dedicated weather and ice advisory service via message or facsimile.

d) REMSCAN will be upwardly compatible with new technology. REMSCAN-provided information will be limited ultimately by the capabilities of the sensors in use. As improved sensors become available, REMSCAN will utilize the new information with, at most, minor technical changes to accomodate new data formats, etc.

4.3 Basic Functional Concept

The REMSCAN system must carry out four major functions:

- capture data, imagery, and other information on ice and related environmental quantities
- capture positional information in order to relate the positions of ice features and user locations to standard maps and charts
- process the data into usable and desirable forms as required
- communicate data and processed information among users, participating organizations, and central processing facilities

Thus, the four major elements of the REMSCAN concept are:

- remote sensing subsystem (RSS)
- communications subsystem (COMSS)
- navigation subsystem (NAVSS)
- systems control and information processing (SCIP) subsystem

Section 5 of the REMSCAN Final Report includes descriptions and primary characteristics of each of the REMSCAN subsystems.

5. DESIGN APPROACHES

Having identified the functions of REMSCAN (i.e., what the system must do) alternative design approaches were examined (i.e., how the system is to do it). Three approaches are discussed:

a) In the Centralized Approach, all image processing, analysis, interpretation, and forecasting functions would be carried out at a central facility to be located presumably in Southern Canada. Field sites would require only data acquisition and display capabilities, and would be serviced by long-range wide-band communications capable of transmitting imagery in near-real time. Skilled ice imagery interpreters would not be required in the field. This approach is close to the original REMSCAN concept.

b) In the Distributed Approach, the capability of individual field sites to acquire, process, and interpret all data, including airborne imagery, necessary to serve their own ice information requirements would be maximized. The central facility would be responsible only for communications between sites and for system housekeeping functions such as SAR aircraft scheduling and supervisory monitoring of vessels. It would maintain an overview of ice conditions commensurate with those tasks. Skilled interpreters would be required on board each vessel, and at each fixed site or cluster of sites. The integration and processing of regional data for strategic applications would be costly. This approach is closest to that being pursued by the M.V. Arctic.

c) The Hybrid Approach represents a compromise between the two other Approaches. The aim is to retain the advantages of local processing and interpretation offered by the Distributed Approach, without sacrificing the advantages of the Centralized Approach for strategic purposes. The key to doing so is the use in the field of interactive image processing techniques to selectively extract significant information from raw imagery for transmission over narrow band channels in greatly compressed form. Using such "edited" imagery, the central facility would assemble information

from diverse sources into an overview for strategic and tactical purposes, and would carry out forecasting and route optimizing as well as housekeeping functions.

The Hybrid Approach was selected because it avoids the major drawbacks of the other two, namely, high technical risk and possible failure to meet all the requirements. With its use of in-field interpretation and processing, the Hybrid Approach is compatible with current practises such as those followed by the M.V. Arctic and it is also compatible with the centralized analysis facility favoured by A.E.S. and by Canmar in the Beaufort Sea. Major technical characteristics of the Hybrid Approach are:

- direct downlinking of imagery to suitable equipped vessels
- on-board image processing with some interpretation
- narrow bandwidth long range communications; transmission of highly compressed imagery
- central facility does interpretation, forecasting, route optimization, geo-referencing
- highly processed tactical and strategic information back-hauled to users.

6. BASELINE DESIGN

This section outlines the design of the various Subsystems consistent with the Hybrid Approach, for a baseline version of REMSCAN.

The baseline version is consistent with an operational scenario comprising:

- limited year-round Beaufort Sea oil production, supported by two Class 10 tankers and a regional centre at Tuktoyaktuk
- production from the Hibernia field with a regional centre at St. John's
- eastern Arctic resupply and grain transportation, with a regional centre at Frobisher Bay
- high Arctic transportation during June-December carried out by an enhanced ice class version of the M.V. Arctic

6.1 Remote Sensing Sub-system (RSS)

Broadly speaking the RSS receives all relevant ice data from sources, both internal and (mostly) external to REMSCAN, from which ice information is produced in the form of colour coded black and white maps, charts and interpretive reports. The RSS is interfaced to other REMSCAN Subsystems for geo-referencing (NAVSS), forecasting and archiving (SCIP), and distribution (COMSS). It is noteworthy that the RSS design concept provides for the collection of a broad spectrum of remotely sensed data, including imagery; however, data is transmitted via the COMSS in only as much detail as is required, (ie. where little detail is required, the data is pre-processed, and for much detail, the data stream is highly compressed so that narrow band channels can be used).

6.2 Navigation Subsystem (NAVSS)

The main factors governing the design of the NAVSS are the requirement for vessel autonomy and the avoidance of duplicating on-board navigation facilities for strictly REMSCAN purposes. Also, reliance on a non-space-based externally referenced navigation/positioning system like LORAN C is stressed. Such a system need not be continuous throughout the area of REMSCAN coverage, merely contiguous, with ships dead reckoning between areas of coverage. Naturally, those geographic areas which are environmentally sensitive or hazardous from a navigation point of view would be assigned first priority for LORAN C type coverage. The roles of the NAVSS are summarized as follows:

- to provide georeferencing, in absolute parameters to all remotely sensed data backhauled to REMSCAN
- to provide strategic navigation information to client vessels
- to enhance tactical navigation accuracies where necessary to ensure safety and efficiency in ice-infested waters
- to supply navigation data to the vessel route optimization function of the SCIP

6.3 Communications Subsystem (COMSS)

A large portion of REMSCAN communications traffic will be non-voice, in the form of digital imagery, facsimile, text, and numerical data. Existing arctic communications, especially for data, are poor or non-existent. Except for the DOC proposed Mobile Satellite program (MSAT), little or no improvement is foreseen. The general lack of communications facilities must be allowed for by use of distributed processing to reduce the volume of information transferred between sites and to impart a moderate degree of autonomy to the remote user. REMSCAN equipment together with related protocols and procedures must be adaptable to extended periods of poor communications.

Long range communications between the Arctic and the REMSCAN central facility will principally be provided by MSAT after service is available in the late '80s. Design limitations will restrict data rate on MSAT to 2400 bits per second, thus constraining the majority of REMSCAN communications to this speed also.

High speed Local Area Networks will be used aboard ships at other REMSCAN sites for data collection and distribution.

Dissimilar equipments owned by users would attach to and function as parts of the REMSCAN network through gateways that perform data communications protocol conversion and similar translation functions. Access to data from non-REMSCAN agencies such as the Atmospheric Environment Service would occur through interfaces, both electrical and procedural, that would ensure rapid, uniform treatment of time sensitive information.

6.4 System Control and Information Processing (SCIP) Subsystem Requirements

Seven functions have been identified:

- assembly: this operation inserts the received data into the database in preparation for use by other subsystems. Incoming data is expected at a rate in excess of 20 Mbytes per day.

- evaluation: this function consists of conducting reasonableness checks on fresh data.

- integration: this function involves merging the data from different sensor types.

- forecasting: this function will attempt to predict future ice distribution. Predictive models of this kind work best when considering as large an area as possible - in this case, the entire arctic - and would require a substantial database of environmental information.

A major spinoff from the forecasting subsystem is the possibility of performing route optimization calculations. Meteorological forecasts will also be required by ships' masters, and could be added to REMSCAN information packages. An additional type of forecasting likely to be asked of REMSCAN is oil spill modelling.

- dissemination: Data on current and predicted conditions must be distributed to vessels, in forms they are equipped to receive. This function comprises those steps necessary to compile Information Packages for users.

- archiving: A record of each forecast and nowcast issued will be retained.

- control: This comprises essentially activity scheduling functions which ensure that activities are performed as intended.

6.5 REMSCAN Organization and Management

A REMSCAN infrastructure composed of a management team and personnel resources would be required, the functions of which would be as follows:

- provide framework for REMSCAN housekeeping (technical, organizational, and financial)
- allocate and manage system resources
- direct priorities for data collection, processing and output products
- liaise with external agencies and facilities
- liaise with users
- regulate and coordinate participation by users
- provide manual and automated (as required) facilities for subsystems, in particular, REMSCAN interfaces and information processing
- operate and maintain special-purpose REMSCAN facilities
- manage functional and technical evolution of system

Some of these functions might be automated and included within the context of the SCIP subsystem.

6.5.1 Fiscal Implications

The fiscal administration of REMSCAN would of course be a responsibility of the REMSCAN infrastructure. The system concept as set forth has some immediately apparent implications in this area and in overall financing as well.

a) The capital cost of the system to the managing organization would be low due to:
   - Reliance being placed on users wherever possible for front end sensing equipment including SAR flights and display facilities
   - Leasing of common carrier communications channels wherever possible
   - Heavy dependence upon existing systems and capabilities (such as Ice Central) in baseline system. Incremental upgrading costs would account for much of the overall capital expenditures.

   Capital costs to users would be variable depending upon their levels of participation and upon the degree of regulation imposed upon them.

b) Operating costs to the managing organization in respect of equipment would also be minimal due to the above considerations. Administrative costs would be dependent upon the size of the regulatory machinery necessary to maintain operating standards and ensure compliance with applicable statutes.

c) Direct cost recovery of system overhead would be possible on the basis of:
   - Fees for service
   - Licensing of users
   - Cost sharing with other organizations (AES, etc.)

7. COST SUMMARY

7.1 Capital Costs

Each Major Vessel	$ 400K
Each Regional Centre	$ 400K
REMSCAN Central Facility	$21,200K
Total	$22,000K

The Central Facility capital cost includes $15,000K for a LORAN-C chain for the North West Passage.

7.2 Operating and Maintenance Costs

Major operating and maintenance costs are personnel-related, and are expected to be significant only for the REMSCAN Central Facility and for the LORAN-C chain.

REMSCAN Central Facility	$4,200K/Yr.
LORAN-C Chain	$2,000K/Yr.
Total	$6,200K/Yr.

7.3 Development Costs

The integrated development costs, exclusive of hardware and software development which are included in the capital cost estimated of 6.1, are estimated at:

Total	$14,000K

LORAN-C development studies represent $250K of this total.

7.4 Design and Development: Actual System

Capital and operating costs for an actual REMSCAN implementation cannot be specified until:

- a detailed assessment of the actual operating scenario to be supported is available
- regulatory requirements concerning ice information are established
- the kind and level of participation by various Government and industrial organizations are established.

The tentative level of effort required is as follows:

- REMSCAN System Definition: 36 man months
- Design and Development: 156 man months

APPENDIX

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